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WITH

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THE

INSTITUTION

OF

CIVIL ENGINEERS.

SESSION 1872-73.—PART I.

November 12 and 19, 1872.

T. HAWKSLEY, President,
in the Chair.

No. 1,342.—"Explosive Agents applied to Industrial Purposes." By FREDERICK AUGUSTUS ABEL, F.R.S., Treas. C.S.[1]

DISCUSSION.

Professor ABEL said he had endeavoured to give a general account of the nature and characteristics of the several classes of explosive agents produced, and to a more or less extent used, as substitutes for gunpowder in industrial operations, and he trusted the discussion of the Paper would serve to elicit information, with regard to their use and relative merits, from persons practically acquainted with their employment.

He had pointed out certain defects of gunpowder, some of which, he believed, were fully established, while others might be open to question. Amongst these were, the variation in its composition and preparation, and consequent want of uniformity in its action. Its deterioration by the absorption of moisture was due to the fact that it was made with special regard to cheapness. The amount of smoke produced in underground operations was a cause of delay and difficulty in blasting; and an important objection was the inevitable liability to violent explosion whenever, either from carelessness or from accidental causes, it was reached

[1] This paper, with the addenda to it, was printed in extenso in the last volume of the Minutes of Proceedings, vol. xxxiv., pp. 327—371. The discussion upon it extended over portions of two evenings, but an abstract of the whole is given consecutively.

by flame or fire of any kind. Many of the accidents in ordinary mining and quarrying operations were undoubtedly due to carelessness; and there was reason to be grateful for the zealous and successful labours of Major Majendie, recently appointed Inspector of Powder Magazines, who had already induced and enforced the adoption of precautions which would greatly guard against accidents in its use and storage.

He might refer incidentally to some experiments at Woolwich Marshes, in which it was demonstrated that the expenditure of heat, by the conversion of water from the solid condition to that of vapour, might serve as a means of effectually protecting powder against the action of fire. It was extremely probable that such arrangements—where the powder was enclosed within fireproof magazines, which protected it for long periods from important change by the action of violent heat—would prove great safeguards against accident in the storage of small quantities for the purposes of trade.

Chlorate of potash, he had pointed out, yielded preparations more violent, because more rapid, in their action than gunpowder, but also more dangerous, and more liable to accidental ignition by moderate concussion. A few of comparatively safe character had been produced as blasting agents, and to some extent used; amongst these were 'Horsley's powder' and 'tutonite,' and also a material obtained by the saturation and coating of bibulous paper with a mixture of chlorate of potash, charcoal, and other oxidisable substances, first devised by Hochstädter for use in small-arms, and recently proposed by Reichen for blasting purposes.

Several preparations had lately been brought under public notice, which, when fire reached them accidentally, or when otherwise exposed to heat in the unconfined state, would behave less violently than gunpowder. The type of these, manufactured at Plymouth some years ago, consisted of spent tan saturated with saltpetre and sprinkled with sulphur. The two most modern preparations of this class were called 'pyrolithe' and 'pudrolythe.' These undoubtedly burnt less violently in open air than the mildest description of blasting powder. In some special experiments instituted to exhibit their powers, they were described as having produced effects which bore advantageous comparison with those of gunpowder.

In the Paper he had entered as fully as the limits permitted into the history of gun-cotton and nitro-glycerine, with reference to their application to industrial purposes. He had described the manner in which Mr. Nobel had succeeded in applying nitro-glycerine, the most violent blasting agent at present known, which, under favourable conditions, might be handled with comparative safety. He had also pointed out that nitro-glycerine was uncertain and highly dangerous for technical purposes, until Mr. Nobel overcame most of its defects by employing absorbent materials as media for its application. The special absorbent which he used was a siliceous earth called 'kieselguhr' obtained from Germany. This earth was saturated with a large proportion of nitro-glycerine, and the material known as 'dynamite' was produced, which was sufficiently solid to be conveniently handled and packed into paper cartridges, and it was readily fired by a detonating arrangement, also introduced by Mr. Nobel. Subsequently to the invention of dynamite, various substances, akin to it in nature, had been brought forward. One of these was 'colonia powder,' a species of gunpowder saturated with glycerine; others were 'dualine,' 'Horsley's powder,' 'glyoxiline' and 'lithofracteur,' the latter differing in some respects from dynamite, but being the nearest to it in general characteristics.

In giving an account of the relative properties of gun-cotton and nitro-glycerine-preparations, such as dynamite, he had dwelt upon the difficulty of instituting accurate comparisons of the force evolved by different explosive agents, and had pointed out that the many experiments in this direction had been attended with only partial success. Very precise statements were often made with reference to the powers of particular explosive agents, as compared with gunpowder. He believed that such statements were all more or less fallacious; they were generally based upon erroneous assumptions with regard to the uniformity of the material operated against, and of other conditions of the experiments, and upon the sanguine views of those interested. If it were possible to devise some method of ascertaining the powers of explosive agents, applied to destructive purposes, in as trustworthy a way as was adopted in testing the strength of iron, steel, and other materials, so that definite values might be assigned to them, it would be one of the greatest benefits that practical men, connected with mining, quarrying, and engineering operations, could have conferred upon them. In America some experiments had been made in this direction which appeared to be of a promising character, but they required further elaboration before they could be put forward with confidence.

In speaking of the relative merits of dynamite and gun-cotton, he had pointed out that in the former, there were advantages which might be considered as counterbalanced by others possessed by gun-cotton, and that both exhibited special defects. One great defect of dynamite which still had to be remedied, and which it was doubtful if in the present state of knowledge could be thoroughly set aside, was the danger of reducing it from a comparatively inert frozen condition to a state in which it could be readily used. Accidents had repeatedly and even recently occurred through the difficulty of introducing or enforcing simple regulations for the thawing of dynamite, or for the application, in a simple and safe way, of the heat necessary to reduce the dynamite from a solid to a plastic condition in which it could be readily used as an explosive agent.

In the case of gun-cotton, little experience in connection with industrial operations could be added to that obtained previous to the last twelve months. Certain defects still remained to be overcome before gun-cotton could be effectually applied under every circumstance as a blasting agent for industrial purposes. He might mention, however, that while the gun-cotton trade had been at a standstill, considerable progress had been made in the Government factory in perfecting its production, and that some new points had been worked out with reference to its application, which promised to be fruitful of important results in naval and military operations, and perhaps also in connection with the industrial uses of the material. For example, it had been found possible, by incorporating gun-cotton with considerable proportions of oxidising agents and compressing the mixtures, to increase the explosive force of the material and at the same time to reduce its cost. As a last point he might notice that gun-cotton could be used in a very damp condition as an explosive agent. It had been thought impossible to use gun-cotton in a damp blasting hole, but it had been proved by Mr. Brown, of Woolwich, that it was possible to detonate gun-cotton even when thoroughly saturated with moisture—a condition in which it was quite uninflammable by ordinary means—simply by exploding it through the agency of a small priming charge of dry gun-cotton fired by a detonating fuze. Charges actually immersed in water, and with water intervening between the separate masses composing the charge, had been exploded by means of a waterproofed priming charge, and the results appeared to be in no way inferior to those obtained in the usual way. He mentioned these last facts as a few points of novelty since the Paper had been written.

Mr. Sopwith remarked that the examination of gun-cotton as an explosive material had come under his attention, and had been the subject of many experiments reported in Parliamentary Papers.[1] These were readily accessible, and were much more accurate than any information he could give from recollection. The only practical point to which he wished to direct attention, was that in comparing the explosive force of different materials it was extremely difficult to form a conclusion by experiments upon rocks, on account of their great variety of structure, and therefore undue inferences might be drawn when the precise character of the rock was not perfectly known. He wished, whenever further experiments were tried, that some endeavour should be made to provide a solid object, as nearly as possible, of uniform density and texture. Such a material he thought would give results more to be depended upon, and approaching nearer to geometrical accuracy, than any that had been yet found in the course of actual experiments in mines and quarries.

Mr. J. G. C. C. Godsman said there was one point he would like Professor Abel to refer to in his reply. Many years ago, when he was in the Navy, the interior of the guns frequently became 'honeycombed' by the action of the gunpowder then in use. Some gutta-percha impressions of the damaged portions of the present service guns had been recently laid upon the table of the Institution, and he noticed, notwithstanding the modern improvements in artillery and in the manufacture of gunpowder, that the same process of 'honeycombing' went on. He attributed it to the action of the powerful acids, generated by the gunpowder, which were evolved at a high temperature during its confined combustion. He should like, therefore, to hear whether or not the new explosive compounds referred to in the Paper were free from that serious disadvantage?

Mr. R. S. France said he should be happy to give the Institution the benefit of any practical experience he had acquired in the working of quarries in the use of various explosive

[1] Gun-Cotton.—Reports relative to the application of Gun-Cotton to Mining and Quarrying operations (House of Commons, 30th April, 1869), contains :—

1. Report of Gun-Cotton Commission, on experiments made at Allenheads on *Ordinary Gun-Cotton*, in October, 1864.
2. Memorandum of the Results of experiments made by Mr. Sopwith and Mr. Abel in September, 1865, with *Granulated and Compressed Gun-Cotton.*
3. Memorandum of the Results of further experiments made by Mr. Sopwith and Mr. Abel in February, 1869, with *Compressed Gun-Cotton fired by means of detonating primers.*

materials. Professor Abel had mentioned several explosives adapted for mining and quarrying purposes, but it was a fact that one, perhaps more, of those explosives, was prohibited from use in this country by Act of Parliament.

Now to those who were in the habit of using many tons of explosive agents, it was a matter of the highest importance that they should be at once powerful and safe to place in the hands of quarrymen. This question of safety was, no doubt, matter for discussion. The power of an explosive could not be recognised without considering its relative safety; and so far as theory had gone, the whole scientific opinion of the country had been at fault. Professor Abel had laid down the theory that gun-cotton was an absolutely safe explosive. That opinion had been endorsed by Major Majendie and other gentlemen of the War Office, and on the faith of it gun-cotton had been extensively manufactured and used. How far that opinion was correct let the explosion at Stowmarket bear witness. He would go further than the manufacture, and say his attention was called to the matter by explosions in his own quarries. There, two men one hot day were nearly blown to pieces while simply pressing gun-cotton into the holes in the ordinary manner. The result was, his men would not again use that material, and he was thrown back upon gunpowder, which was not adapted to all the purposes of quarrying. The accident happened early in the afternoon, and it was a singular coincidence, that gun-cotton explosions had always taken place between noon and 2 P.M. He had no pecuniary connection with the manufacture of any explosive, and was solely interested, as a quarry proprietor, in obtaining the best that could be procured. He must pay the highest compliment to Mr. Nobel for bringing nitro-glycerine from a raw preparation into a condition in which it could be safely used. It was just at the time of the gun-cotton explosion in his quarries that the nitro-glycerine preparation, in the form of Nobel's dynamite, was introduced, and he wished to distinguish it from pure nitro-glycerine. Undoubtedly, pure nitro-glycerine was the best explosive that could be used in quarrying operations, provided only absolute safety could be ensured in its transport; he would not say storage, because he was not aware of any accident from storage; but if safety in transport could be secured, he believed it would be found the cheapest and most effective. Unfortunately, however, the accidents at Carnarvon and Newcastle had proved it to be a highly dangerous material to transport, and a legislative restriction on the transport of raw nitro-glycerine was properly considered necessary. Now it must be borne in mind that Professor Abel, as the Chemist of the War Office, was mainly instrumental in advising the total exclusion, not only of nitro-glycerine, but also of its preparations, in lieu of which he advised the use of gun-cotton. No inquiry was ever made into the alleged dangers of nitro-glycerine preparations. The measure was taken up and carried by the Government at the instigation of their officers. It was said in the Paper, "This discovery led at once to the production by Nobel of solid, or more or less pasty, preparations of nitro-glycerine, which, under the name of dynamite, were first brought before the public in 1867, and the most perfect of which constitutes, as now manufactured, one of the safest, most powerful, and most convenient explosive agents applicable to industrial purposes."[1]

He had observed that no evidence was taken before the Parliamentary Committee as to the desirability of passing the prohibitory Act with regard to nitro-glycerine and its preparations. The Bill was hurried through Parliament. It came before a Committee of the whole House at 3 A.M. But there were not wanting at that hour, advanced as it was, representatives of the mining and quarrying interests, thoroughly informed of the non-desirability, in fact the mischief, of passing so prohibitory a measure with regard to new explosives. The question at last came on for discussion, and arguments were raised on both sides; and it was at one moment rather doubtful which way the discussion would go, when Sir John Hay read this letter from Professor Abel:—

Woolwich, 10*th July*, 1869.

"DEAR SIR JOHN HAY,

"In reply to your inquiries respecting nitro-glycerine, the production and properties of which have been made the subject of careful study and extensive experiment by me, I have to express my firm conviction that such appalling accidents as that which recently occurred in Wales, cannot be guarded against by the enforcement of any measure short of an absolute prohibition of the importation, transport, and storage of nitro-glycerine, or of any preparation of that material. The explosion near Carnarvon was but a repetition of catastrophes of similar nature which have occurred within the last few years in other countries, and are ascribable to the readiness with which nitro-glycerine explodes when subjected to concussion or friction, especially if it be undergoing spontaneous change, to which it is very prone, however

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xxxiv., p. 343.

perfect the system of manufacture. No apprehension need be entertained that the enforcement of prohibitory regulations however stringent and complete, with respect to nitro-glycerine and its preparations, would be detrimental to the interest of mine and quarry owners. The discoveries recently made with regard to the application of gun-cotton as a blasting agent have placed this material quite upon an equality with nitro-glycerine as regards its power; and there is this important difference between the two materials. No effectual means are known of guarding against the accidental explosion of nitro-glycerine, which must inevitably be productive of fearfully destructive results; while compressed gun-cotton (the only form in which it is now manufactured) may be transported with quite as much safety as gunpowder, and, if ignited by any accident, produces considerably less destructive results than even the latter material, because gun-cotton simply burns without explosion, unless very strongly confined (as in guns, shells, or blast-holes), or unless it is fired with a particular kind of fuze. If proprietors of mines and quarries continue to cling to a preference for nitro-glycerine or any preparation of it, such as the substance called dynamite, for special kinds of blasting operations, the explosive agent should be manufactured exclusively at the particular localities where it is to be used, and only in such quantities as are required from time to time, no reserve stores being permitted.

The preparation of nitro-glycerine is not a difficult operation, and the above system is pursued in some localities on the Continent where that substance is employed.

By introducing the restrictions above indicated with respect to nitro-glycerine and its preparations, such accidents will still not be guarded against, as occurred not long ago at Newcastle, consequent upon the great readiness with which nitro-glycerine freezes (whereby it becomes much more sensitive to explosion by concussion or a blow), and upon the generally dangerous character of the material; but these accidents and their disastrous results will become confined to the localities where the nitro-glycerine is actually used, although even then, others employed in or near such works, may suffer through the instrumentality of those who persist in having recourse to this fearfully dangerous explosive agent. I am, dear Sir John Hay,

Yours faithfully,

(Signed) F. A. Abel."

" Rear-Admiral Sir John Hay, Bart.,
M.P., F.R.S."

Now the experiments which the War Office Committee made at his quarries proved—and it was so admitted in the Paper—that nitro-glycerine, in its frozen state, was not sensitive to concussion or explosion. But the Author now said dynamite was the most satisfactory explosive that could be used. This matter was to him and to other quarry proprietors of far higher importance than the question whether Professor Abel had contradicted himself within the last few years. It was of the highest importance also to the community, because every fraction of the material which came from the quarries was removed from the solid rock by explosive agents, and it was eminently desirable that they should not only be safe but economical. The question of cost was one of considerable importance to those using explosives. Let there be free trade in this as in other things, and let it be proved by practical use whether the explosives were safe or not.

He now came to speak of explosives as far as he had had experience in them, and he was the only quarry proprietor to whom some of the materials had been sent for trial. Taking them in their order, gun-cotton was a fine and clean explosive, and did its work very well, but it nearly killed his men in using it. Then dynamite was at first prohibited, but he did not think a more powerful or a safer explosive could be manufactured. The infusion of nitro-glycerine with earth made it compact for putting into holes in cartridges; whereas, in a liquid state, certain portions of nitro-glycerine always adhered to the sides of the bore holes. On that account Mr. Nobel's plan of forming it into cartridges was a great improvement. Gunpowder was excluded from the term explosives, from which it differed in action. When a bore-hole was charged very tightly with gunpowder, it often acted as a cannon, and the ramming was blown out. He would explain the term 'explosives' by saying that if it were attempted to fire a ball from a cannon with nitro-glycerine or gun-cotton, the cannon would be broken into a thousand pieces before the ball reached the muzzle. Dynamite was undoubtedly a great improvement upon raw nitro-glycerine, but while science went on improving the manufacture of explosives, he was sorry to say that England could not lay claim to any of the inventions or improvements. The seat of the invention of gun-cotton and nitro-glycerine was in Germany, where patents were difficult to obtain, and where considerable enterprise had been shown in making the necessary experiments and trials. Dynamite was an improvement upon raw nitro-glycerine, but it was faulty in some respects. Nitro-glycerine in a raw, or even in a compound, state was exceedingly sensitive to cold, and remained frozen at a temperature of 50°. He did not think it could be thawed under 60° or 70°. The best mode of thawing he found to be by placing it in a heap of horse-dung, and it was a less dangerous plan than thawing it by fire. Recently, near Carnarvon, two men were thawing dynamite upon a hot stove, when it exploded and killed them. It was desirable to guard against such an occurrence by the introduction of a preparation not quite so sensitive to cold, and which would stand the changes of climate better than dynamite. He would like to see a committee of practical men belonging to the Institution devote their attention to the subject, and he would give them all the assistance he could in the use of his quarries and materials in arriving at a decision.

The inventors of litho-fracteur had added to a dynamite composition a certain amount of explosive material, and reduced, not only the quantity of nitro-glycerine, but also the proportion of earthy matter. Dynamite consisted of 75 per cent. of nitro-glycerine and 25 per cent. of infusorial earth. Litho-fracteur consisted of 52½ per cent. of nitro-glycerine, 22½ per cent. of infusorial earth, and 25 per cent. of explosive mineral substances which Messrs. Krebs had, up to this time, kept secret. When he saw the account of what the Prussians did with litho-fracteur in the late war, he assumed it would be serviceable in quarrying operations, and, on his application, Messrs. Krebs sent over an agent with some of the material. He had satisfactorily used it for nearly two years, and he could not detect any diminution of strength in consequence of the less percentage of nitro-glycerine. Now looking to the mistakes scientific men had made in these matters, he was not desirous to be thought a 'scientific man.' He believed as soon as science was introduced in the working of quarries they would cease to pay. Quarry proprietors must look after the safety of their men, and must give them the best explosives. Whilst there was no diminution of power in the litho-fracteur, it proved to be an explosive more readily available under the varying conditions of temperature. He had, during the month of October, 1872, on several days fired holes with dynamite and with litho-fracteur, the same means of detonation being used in each case, and the litho-fracteur was unquestionably the surest in exploding.

There were other modes of proving this. He had been asked to go with the directors of an insurance society to the Bristol Channel to blow up a vessel that had sunk there in a depth of 40 ft. of water. He went with them, but, unfortunately, owing to the Government restriction, they had not enough litho-fracteur, and had to make up the deficiency with dynamite. The experiment took place last March, on rather a cold day, when the dynamite sent down for the purpose was frozen and useless. He looked round and saw some brick-yards about a mile distant. The dynamite, about 3 cwt., was put on the shoulders of six men, and carried to the brick-yards in the hope of thawing it. The brick-kiln was too hot to be walked on, and the wooden cases of dynamite, when put on the top, got so hot that they could scarcely be touched; but paper being a non-conductor of heat, and the cartridges being packed in paper, though the wood outside was so hot the paper was not even warmed. Upon this, the cartridges were unpacked and placed upon the walls of the kiln, and after they were well warmed, they were repacked, and the vessel was blown up with them. He repeated that Mr. Nobel's preparation was a valuable one, but he had to deal with a material extremely sensitive to cold, and practical men wanted the explosive which would give the best results with the least risk and trouble.

There was one other explosive he had been using for the last month, called 'pudrolythe.' It was a simple-looking substance, but it was a remarkably good explosive, better than gunpowder, gun-cotton, dynamite, or litho-fracteur, or any other explosive he had used, under certain circumstances; but those circumstances were so exceptional, that it was difficult to use it to any great extent. If a hole, perfectly tight, and sunk in very hard rock, could be ensured, with no chance of any of the material escaping, then pudrolythe was the safest and best explosive, because it had not the tendency that gun-cotton and nitro-glycerine possessed of shattering particular classes of stone.

The application of gun-cotton or nitro-glycerine to homogeneous stone shattered it so that it entailed much loss; whereas an explosion of the pudrolythe, owing to its slow burning, lifted up the whole mass of stone and dislodged it. He hoped the general interest evinced on the subject would lead to improvements, and he believed that with fair play explosives would be improved; but so long as manufacturers were hampered by Government restriction, there would be no progress. He thought it was no concern of the Government if quarry proprietors chose to blow off their own heads. Such fatherly legislation should be reprobated: let there be fair-dealing and no favour.

Major BEAUMONT, M.P., R.E., said he should not touch upon the chemical aspect of the question, because that was a subject with which he did not profess to be acquainted, but on the practical working of explosives. There was no desideratum connected with mining which was likely to receive satisfactory solution at the hands of scientific men of more importance than the manufacture of safe and efficient blasting agents. The question of applying machinery to the driving of drifts was one apart from this; but as soon as the holes were made, it was necessary to have recourse to explosives as the only means by which the rock could be shifted. When a given number of holes were put into a heading, the powder was only able to shift a certain amount of rock; the position of the holes might be altered for the purpose of attacking the rock to more advantage; but it was obvious in any case, the increased efficiency given by more powerful explosives—even with hand labour—must have greatly accelerated all mining operations. In the case of machine-drilling, it would be more obvious than in the case of hand-boring, as the position of the holes was less readily changed; therefore any means by which the power of explosives could be improved, very materially assisted industry in connection with mines; and he thought he was in a position to say that was practically the case. With the use of any of the powerful explosives under discussion—whether it were gun-cotton, dynamite, or litho-fracteur—it might be calculated that a gallery could be driven 25 per cent. quicker in hard rock than where gunpowder only was employed. With machine-drilling, the difference would be from 30 per cent. to 50 per cent. in the increase of speed—irrespective of that due to the use of machinery—and where a material could be employed as powerful as pure nitro-glycerine, he had little hesitation in saying the difference would be much greater.

He would give results of his experiments with reference to gun-cotton, dynamite, and litho-fracteur. His experience had been confined almost entirely to tunnel-driving by machinery, and therefore he had been compelled to use these explosives; and he did not think he had fired any holes, made by machinery, with powder. He commenced with gun-cotton, the material in the market at the time, and the results were such as to show he had not over-estimated the value of that explosive in his calculation of increased progress of the work, namely, from 20 per cent. to 30 per cent. The gun-cotton was made by Messrs. Prentice, under the patent of Professor Abel. He found it simple to handle, and he believed it was less dangerous to transport than gunpowder. It did not require to be kept drier, but although it shifted a greater amount of rock, it was more expensive. The question was, whether the extra cost was, or was not, compensated for by the extra speed of the work, a matter which would depend on the circumstances of each case. He thought he could shift a larger amount of rock with a given value of gunpowder than of gun-cotton; but it would take a longer time.

The diamond drill he used made a cylindrical hole, true to the $\frac{1}{16}$ of an inch. It was important that there should be no air-space between the blasting agent and the rock, so that the charge should completely fill the hole. Messrs. Prentice made some gun-cotton charges, the successive diameters of which varied by $\frac{1}{8}$ of an inch, and the cartridges had therefore to be jammed into the hole, when the diameter of the latter was in excess of that of the cartridge. In nine hundred and ninety-nine cases out of a thousand the results were satisfactory; but the time came when, in forcing the cartridges into the holes, an explosion took place. Unless the ramming was very violent, according to the theory of the action of gun-cotton under such circumstances, it ought only to burn. In some cases the gun-cotton, in being forced home, had done so, but in others it exploded with a violent detonation. With precautions against this source of accident, he thought it might be safely used, as it was quite equal in explosive qualities to litho-fracteur or dynamite.

The explosion at Stowmarket resulted in throwing gun-cotton out of the market, and in extending the use of dynamite, which, being uninfluenced by water, could be employed in shafts and headings without water-proof cases, and, being plastic, could be squeezed into the holes so as to fill them entirely, by which means the difficulty with gun-cotton in the cylindrical form was got rid of. The explosive force of gun-cotton and dynamite was about the same; and the smell, as far as he knew, was as powerful in the one as in the other; but a person could retire in time to prevent any bad consequences. He had been in headings where the men worked for a considerable time together, and they would not take the trouble to lead a pipe from an adjacent air-supply to bring up fresh air; in fact, the smell need be no bar to the use of these materials in headings; but at the same time, it was necessary to supply some special means of ventilation. When machinery was worked by compressed air, nothing else was necessary. The only opportunity he had of trying litho-fracteur was in experiments made by Mr. France, who fired two or three shots in a heading, driven by the Machine Tunnelling Company at Wigan. The trial was not sufficiently extensive to enable him to speak with confidence as to the relative power of the material, because a single trial was not enough to judge by, and the circumstances of each case were so different, that half a ton of explosives might be used before an opinion could be formed as to the relative value of each. He believed litho-fracteur to be, for practical purposes, fully as powerful as dynamite and gun-cotton; and as far as he could judge, he did not think there were was any decided difference between the three. Whether the component parts of litho-fracteur were as permanently blended as in dynamite he would not say; but he was inclined to believe that the nitro-glycerine in the former was not so well held as it was in the latter; and, consequently, if he had a couple of tons of litho-fracteur to store, he should look more carefully to see that there was no exudation, than in the case of dynamite. Exudation was the real source of danger in this class of material. Perfect litho-fracteur or perfect dynamite, he believed would, under ordinary circumstances, be safe; but if they remained for a length of time in store, or were subject to the shaking of railway travelling, danger might be anticipated.

He had used dynamite at Bristol in the construction of a tunnel for the Great Western and Midland Railway Companies, and one difficulty experienced in using it consisted in the fact that it froze at a temperature higher than the freezing point of water. To overcome this difficulty, tin cases were made with double linings, the cases being put in connection with the exhaust pipe of an engine, so that the tins were kept hot without pouring water into them. At that time he had no idea that any danger would be likely to arise from this process: he had believed that while the temperature was not above 212°, the dynamite would not explode, but he had to alter that opinion. The tin was about 2 ft. long, 11 in. wide, and 11 in. deep: and it held sufficient cartridges for two shifts. The cartridges were supposed to be cleared out at the end of each shift or firing; but it transpired on one occasion that two or three cartridges having been left in for an indefinite time, exploded. The amount of material was only of the value of 9*s.* or 10*s.*; but the engine-house, built of wood, was blown down; and the windows of houses on the opposite side of the road, about 150 yards distant, were driven in. Fortunately, no lives were lost. It was concluded that the dynamite, having been left in the tin for a prolonged period, and having been thereby subject to alternate raising and lowering of temperature, had been decomposed; a change aided, perhaps, by the dynamite touching the metal of the case, and producing spontaneous combustion. Under such circumstances it did not burn, but went off with a violent detonation. Afterwards he gave orders that the dynamite should be thawed with water poured in at a lower temperature than 212°, and that only immediately before the charges were used; he also directed the tins to be lined with felt. It was most desirable to determine in an authoritative manner the dangers incidental to the use of explosives; as it was a matter of extreme importance for practical men to have the best it was possible to produce. It was no use to say the chemist was able to prepare safe compounds in his laboratory if they could not be employed by practical men. One reason against the use of dynamite was that the railway companies would not carry it. When he wanted a ton he had to cart it, however distant, to the place of destination. He was of opinion that it was less dangerous than gunpowder, both to transport and to store. It was clearly the duty of the Government to take such action as should determine whether it was, or was not, a dangerous material to carry. The question submitted to the late War Office Committee referred only to litho-fracteur; but the inquiry should have included in its scope the whole question of explosives. If any new compound of that nature was invented, it should be experimented and reported upon, so that the real danger in carrying, or storing, it might be known. As a Member of Parliament, he would do his best to urge that course upon the Government.

Mr. Perry F. Nursey said that whatever objection might be taken to some of the clauses of the Act—and some of them were open to objection—he considered it to be, as a whole, one of the most salutary acts that had ever been passed. At the time of its introduction, explosions of nitro-glycerine, attended with disastrous results, had occurred in England, Wales, the United States, Australia, the West Indies, and other places. It was therefore necessary, for the public safety, that restrictions should be placed upon the transport, storage, and use of that dangerous though highly useful compound. At that time, however, science was developing new combinations of nitro-glycerine and other substances, the effect of which was to reduce, if not to remove, the danger attending the use of nitro-glycerine compounds. Mr. Nobel especially had controlled the power of nitro-glycerine in his dynamite, and Messrs. Krebs had effected a similar object in their litho-fracteur. The Act of Parliament in question specially provided that if it could be proved to the satisfaction of the Secretary of State that any nitro-glycerine compound could be transported, stored, and used with safety, then, that he should authorize its introduction for industrial and other purposes. That was the point which should be explained to those who were anxiously desiring a powerful and safe explosive for the prosecution of their works, and to those who were under the impression that the Act utterly prohibited the introduction of those compounds. That it was not so, was proved by the circumstance that the Government not long since had granted a license for the manufacture of dynamite and of Horsley's blasting powder. The War Office Committee on explosives had reported unfavourably upon litho-fracteur with regard to two points—the exudation of nitro-glycerine under heat, and the ready dissolution of the compound in water. In practice, no case of exudation had ever been met with, but it was conceivable that a slight supersaturation had taken place in the manufacture of the samples experimented with by the War Office Committee, which would result in exudation under heat. But steps had been taken to prevent the possibility of any recurrence of the defect, and that, coupled with the fact that ready dissolution in water had been overcome by substituting nitrate of baryta for the nitrate of soda previously used, led to the expectation that, at no distant period, the Government would sanction the introduction of litho-fracteur as it already had, that of other nitro-glycerine compounds.

Turning to the immediate subject of the Paper, he would refer to the statement made by the Author, that litho-fracteur was a compound of nitro-glycerine, 52 parts; siliceous earth and sand, 30; powdered coal, 12; nitrate of soda, 4; and sulphur, 2. That was not the exact composition of litho-fracteur, which consisted of $52\frac{1}{2}$ parts of nitro-glycerine, $22\frac{1}{2}$ of kieselguhr or infusorial earth, and 25 of other explosives. What those other explosives were would shortly be known to the public, as litho-fracteur had recently been patented in England. The Author also stated, that with respect to power, it was difficult to conceive that a considerable proportion of the nitro-glycerine contained in dynamite could be advantageously replaced by a crude explosive mixture, less powerful in its action than that liquid. Mr. Nursey would not combat that statement with his own opinion and experience, but would meet it by an extract from a "Report on Litho-fracteur, &c., from the Engineer Company of the Guards under General von Kamecke, President." The report was issued by the Prussian Government, and bore date the 18th of November, 1869. It concluded with the following *résumé*. "The advantages of litho-fracteur over dynamite and dualin consist especially in the fact that, relatively to the other explosives named, it possesses the greatest power in the smallest bulk." The Author further stated, that with regard to safety, it was obvious that the ready susceptibility of a particular nitro-glycerine preparation to explosion, by blows or concussion, was likely to be in direct proportion to the amount of nitro-glycerine which it contained. That being the case, it followed that as litho-fracteur contained only $52\frac{1}{2}$ per cent. of nitro-glycerine, whilst dynamite contained 75 per cent., the former compound must possess the element of safety in a higher degree than the latter.

As regarded the application of violent explosives to industrial purposes, three conditions mainly had to be met by any substance which might be utilized for that purpose: the first was safety, the second power, and the third economy. He had both made and attended numerous experiments with various explosives during the last six or seven years. Many of the compounds promised well, but practically, gun-cotton, dynamite and litho-fracteur, were the only violent explosives which had outlived experiments, and had become recognised agents in the prosecution of industrial enterprise. The experiments and practical trials to which he had referred had established the existence of the three conditions already named. In July, 1868, Mr. Nobel carried out a series of experiments with dynamite at the Merstham quarries, illustrative of those points; several charges were fired in the workings, which gave excellent results, such as put into the shade the ordinary performances of gunpowder there. Perhaps the most striking experiment was that made with a cylindrical block of wrought iron $11\frac{1}{4}$ in. diameter, $12\frac{1}{2}$ in. long, and bored through the centre with a hole 1 in. diameter. The hole was filled with dynamite, about 7 oz. or 8 oz. being used, and when exploded, the cylinder was split in two, one-half being thrown 80 ft. in one direction, where it was stopped by a rock, and the other half in an opposite direction, being stopped 50 ft. away by a railway bank. A singular circumstance in connection with that experiment was, that on examining the iron after the explosion, the bore hole was found to be enlarged to $1\frac{3}{4}$ in. at the centre, tapering to the original diameter at a distance of about 3 in. from the ends. The bore was not plugged, and the explanation of the enlargement probably was that the explosion, although practically instantaneous, commenced slowly at one end, where a portion of the charge was exposed to the resistance of the atmosphere only —its intensity gradually increasing as it neared the centre, where it reached its maximum, and as gradually declining towards the other end of the bore which was open to the atmosphere. The area of metal thus torn through was about 120 square inches.

A great number of experiments had been made during the past two years with litho-fracteur, with the view of demonstrating its safety and strength, and its applicability to industrial purposes. It had been proved to be safe under all ordinary, and many extraordinary, conditions. It had been subjected to a temperature gradually increasing to 374°, when it merely smouldered away; it had been tried in various ways under the condition of a railway collision, by being jammed between railway trucks descending, unchecked, an incline 500 yards long, with a gradient of 1 in 8; it had been thrown from great heights, and burned in confined spaces without any explosion occurring. Its power had been illustrated in the workings at Mr. France's quarries at Nantmawr and Breidden, where, in one instance, about 20 tons of limestone were brought down with 17½ oz. of litho-fracteur. As a proof of its great energy, two double-headed rails, 4 ft. 6 in. long, weighing 75 lbs. to the yard, were laid on each other, side uppermost, the ends being supported on timber bearers 18 in. high, the rails having a bearing of 3 ft. 6 in. On the top of the rails in the centre, was placed 1 lb. 5 oz. of litho-fracteur tamped with paper —the wrappers of the cartridges—and five pieces of old railway sleepers. The explosion made matchwood of the sleepers, hurling the fragments in all directions, and breaking both rails; the halves of the rails were thrown some distance apart, and a depression or basin was blown out of the ground under the line of the explosion. The combined area of metal severed in the two rails was 17·2 square inches; a wrought-iron girder, having 17 square inches sectional area, placed in a similar position, would require about 100 tons to break it, so that it was clear an enormous power was developed by the 21 ozs. of litho-fracteur exploded in an unconfined condition on the rails. Numerous experiments had been successfully carried out under water with litho-fracteur, which illustrated its usefulness and reliability in sub-aqueous operations. Another instance of the absolute amount of work done with a definite quantity of that compound recently came under his notice in some blasting operations at the porphyry quarries of Quenast, in Belgium. Two holes, 5 ft. deep, and 2 in. diameter, were bored vertically into a plateau of the hard graystone rock. The plateau, which was of irregular shape in plan, measured 32 ft. long by 25 ft. wide, and the holes were charged respectively with 1 kilogramme and 1½ kilogramme of litho-fracteur tamped with water. The explosion displaced about 40 cubic inches of rock, and cracked and rent the plateau throughout its entire length and breadth, for a depth of 10 ft. down to the bottom of the quarry. Practical work had been done with litho-fracteur for the past five years in Germany, during which period it had been used for industrial and engineering, as well as for military purposes, without any accident occurring. It was, in fact, perfectly safe, as was also dynamite, except where carelessness or foolhardiness brought about disaster. The only danger was in the preparation of the nitro-glycerine for dynamite, from which, he had been informed by Mr. Nobel, accidents had resulted. In preparing the nitro-glycerine for litho-fracteur, Messrs. Krebs had introduced a new principle which insured immunity from accident, and no casualty had occurred at their works during the five years they had been in operation. The boring of the St. Gothard tunnel was to be carried out by means of litho-fracteur, 25 tons having just been ordered for that purpose. The extent of the work, and the hardness of the ground, might be inferred from the fact, that it was estimated by the engineers that at least 1,500 tons would be required to complete the work.

Mr. C. Douglas Fox thought it might be interesting to the members to see the result of the experiment with dynamite at Merstham to which reference had been made, and he had therefore placed upon the table the piece of wrought iron which had been torn asunder as described. He had also brought a piece of plate iron, into which, during the same experiments, a tin canister had been driven in small fragments by the explosion of the dynamite.

Major Majendie remarked, in regard to what had been called "paternal legislation," and especially in reference to the allegation that, "it was no concern of the government if quarry proprietors chose to blow off their own heads," that such a view of the question was really altogether beside the issue. As a matter of fact it was not the heads of quarry masters that were blown off, but those of their unfortunate workmen. He was not aware of a single accident having occurred to the person of a quarry proprietor. The sufferers in a recent accident near Carnarvon were the foreman and workmen. The people imperilled by the accident referred to by Major Beaumont, and by the accidents in Cornwall from the explosion of dynamite, were not the mine or quarry proprietors, but the workmen; while the persons blown to pieces by the accident near Oswestry were four workmen and two little boys. It seemed to him if the workmen were the persons who suffered, they would be the proper parties to contend for free trade in self-immolation. But even supposing they as a body said, "We object to this legislation; we don't want to be interfered with; we will take the risk;" that would not be sufficient ground for the absence of all restrictive legislation. The public had surely some voice in the matter, for it would be anything but safe to have free trade in the manufacture and transport as well as in the use of explosives. One of the great dangers with nitro-glycerine was in its transport, that was to say, outside the quarries altogether. In the accident at Colon, where about forty lives were destroyed, and in the accidents at Carnarvon and Newcastle, the occurrences were entirely independent of the working and use of these explosives, but were occasioned solely in their transport. The position in which the factories ought to be placed, in respect of the isolation of the buildings and the protection of the workmen, should also be considered, and the manufacture and storage ought not to be carried on independent of all restriction. The public had a right to require that no manufactory of explosives should be established without sufficient isolation from habitations; and if these materials were to be carried along the public highways, they had a fair right to ask for due protection from the consequences of accident in the transport. As a matter of fact the public appreciated these things very keenly, and if they had their own way with regard to explosives, the restrictions would really be more severe than any that had yet been applied. Take, for example, the action of railway managers. Major Beaumont stated he was precluded from using certain kinds of explosives, not because of legislative restrictions, but because the railways refused to carry them except at prohibitive rates. Major Majendie had collected the presentments of eleven coroners' juries within a few years, in which they had urged the necessity for strong measures with regard to the manufacture, transport, sale, and storage of explosives; and all who had witnessed an explosion, or had seen the victims of it, were compelled to believe that there was another view of the question, quite distinct from that of the quarry proprietor. In short, it was useless to argue that there should be free trade in explosives because the non-use of explosives interfered to some extent with mining operations. But while he thought restrictive legislation was necessary with regard to these materials, he was prepared to define the limits to which restrictive legislation should go. These limits were correctly laid down by Sir George Grey, when, in 1864, he directed Colonel Boxer to make inquiries with a view to amended legislation. Sir George Grey then stated that restrictive legislation in trade was to be justified only by considerations of public safety. He thought that dictum was perfectly correct. Restriction in trade was bad in itself, and ought only to be adopted to remedy something worse, which could not be remedied in any other way; and he thought if that principle was applied to the existing legislation as to preparations of nitro-glycerine—which was an extreme example of legislative interference—it would be found that the Nitro-glycerine Act satisfied the test. It was necessary, within reasonable and moderate limits, to restrict the use of explosives, and up to the point of public safety it was clearly necessary that legislative restriction should be adopted with regard to them.

Mr. A. A. Langley said he had no interest in any quarry nor in any patent relating to explosives, but he had used gunpowder, gun-cotton, and nitro-glycerine in carrying out extensive mining operations. He let the work to the men "by the piece," they providing their own stores, powder, gun-cotton, &c.

He invariably found that the miners used gun-cotton in slate rock, which he considered the best proof that they were enabled to make most progress with it. From his own experience he had no hesitation in stating that its use effected a great saving in labour in mining operations in slate rock, such as driving headings or levels. It was a common practice with miners to drill a hole about 2 ft. deep, and to charge it with two or three cartridges of compressed gun-cotton, each about $1\frac{1}{2}$ in. long, and about $\frac{7}{8}$ in. diameter, and then to add a layer of about 2 in. of ordinary blasting powder. On one occasion he drove by hand, using gun-cotton, a level 7 ft. high by 7 ft. wide, in slate rock, 22 lineal yards forward in one month, and he had not heard that a greater progress had ever been made without boring machines. Gun-cotton, however, was not applicable to quarrying slate blocks for manufacture, being so sudden in its action that it cracked the rock and rendered it worthless for slate making. He believed it to be quite as safe as ordinary blasting powder when the men were accustomed to it.

He had used oil of glycerine in flint and other rocks of that description, and he believed a saving of at least 20 per cent. or 30 per cent. was effected in some cases. But it was impossible properly to compare the value of one explosive with another, unless the description of work performed was also taken into account. What was suitable for one rock might be bad for another. It depended upon the nature of the rock, the number and direction of the joints, and the manner in which the mining had to be carried on.

He believed if railway contractors would turn their attention more to these matters they might often effect a considerable saving in tunneling by the employment of gun-cotton and other explosives of a similar nature.

Mr. T. Mason said he wished to give a brief history of the manufacture and use of a new explosive called 'pudrolythe.' The advantages claimed for it were, that it was safe when surrounded by the atmosphere, and, unless tightly tamped, would not explode; that it was considerably cheaper and one-third more powerful than gunpowder, and that the system of manufacture was easy; that there was, comparatively, an absence of smoke on explosion; that water would not spoil it—for when dried on a hot plate, it was just as good as it was previous to being wetted; and that no deleterious gases were emitted by the explosion. He was confirmed, in these statements, by certificates from distinguished Belgian chemists and engineers, and in Belgium there was no hesitation on the part of railway managers to its transport as ordinary traffic. It had received the approval of Mr. Hayward of Carnarvon, where the dynamite explosion had taken place, who stated that he considered pudrolythe was the best explosive yet introduced. Mr. Mason had witnessed numerous experiments with it by Mr. George Farren, Assoc. Inst. C.E., the manager of the Welsh Granite Company, the results of which he submitted to the Meeting. Understanding that the powder he had first received had been made some time, he thought it might possibly require keeping to improve by age, and with the view of testing this question he arranged it in four distinct parcels, for experiment, on different kinds of rocks, at Lord Penrhyn's quarries, and he found that within fifteen minutes after mixing the compound it exploded a charge. A like course was adopted on the following day at the Festiniog Quarries. The experiments were also carried on underground for four hours within a distance of half a mile, in the Lisborne Lead Mine, Aberystwith, and the workmen unanimously said the smoke generated was not so great as from gunpowder, and that it had no ill effect upon them; that particular course of trials was completed at Llanymynech Lime Rocks, all the experiments resulting satisfactorily. Similar reports had been received from Cornwall.

The material consisted of 3 parts of nitrate of soda, 3 of nitrate of baryta, 3 of spent tan, 5 of sawdust, 12 of sulphur, 8 of charcoal, and the balance of one hundred was made up of nitrate of potash. It was used in the same way as ordinary blasting powder, and the charge was rammed down with an iron bar, as pudrolythe would not explode by fire from flint and steel, nor by concussion. It might be struck on an anvil without exploding. As compared with ordinary blasting powder, only two-thirds the quantity of pudrolythe would be required. If slate was to be removed bodily from the bed, the hole was lightly filled with the powder, or the strength of the charge reduced, when, instead of shattering, it would lift the rock directly off the bed. Greased cartridges were used when the holes were wet, and a particular form of cartridge to exclude the atmosphere when the holes were faulty.

Mr. C. J. Appleby had seen nitro-glycerine used in larger quantities than had been spoken of. At Harling there was an old sunken jetty which it was necessary to remove. It had been constructed in a depth of from 10 ft. to 15 ft. of water. The parties who took the contract brought their plant to the spot, consisting of two large dredgers, with apparatus for drawing piles; but the piles were so worm-eaten that they broke off, leaving the stumps, which injured the buckets, and gave them very great trouble. After they had been at work for six or eight weeks it was resolved that they should blow the jetty up piecemeal, and take away the fragments by degrees. Both dynamite and litho-fracteur were used in the first instance, but it was found that a better result was obtained from litho-fracteur than from dynamite, and, in consequence, dynamite was abandoned and litho-fracteur used entirely throughout the remainder of the work. The mode of working adopted was suggested and carried out by M. J. J. van Rietschoten. About 10 lbs. of litho-fracteur were put into an ordinary wooden box, the centre cartridges having detonating fuzes attached to them. The box was slid down a pile and was held by a pole at the point where the explosion was required. They generally fired from five charges to ten charges per day. Sometimes they had a miss-fire, in which event they simply lowered another box of litho-fracteur on the top of the first, and, when fired, both shots were heard and felt. Adopting the litho-fracteur for the removal of the jetty had proved a complete success, and the work was executed for one-half the money and in one-tenth of the time estimated.

Mr. Orlando Webb said that a statement had been made that, in consequence of the great diversity of the structure of rocks, the only way to arrive at a practical conclusion on the value of explosives was from actual results. He chanced to have obtained the statistics of driving a railway tunnel with gunpowder, gun-cotton, and dynamite, to which he would briefly refer. The distance driven in a given line with gunpowder was 8 yards forward, with gun-cotton 14 yards, and with dynamite 15 yards. The quantities used of each explosive were—for the 8 yards with gunpowder, 756 lbs.; for the 14 yards with gun-cotton, 169 lbs.; and for the 15 yards with dynamite, 165 lbs. The tunnel was an ordinary railway tunnel. The number of bore-holes or shots per yard was 31 with gunpowder, 18 with gun-cotton, and 17 with dynamite. Taking the value of gunpowder at £2 per barrel of 100 lbs., it gave $4\frac{4}{5}$*d.* per lb.; gun-cotton, at £10 per cwt., gave 1*s.* 10*d.* per lb.; and dynamite, at £10 10*s.* per cwt., gave 1*s.* $10\frac{1}{2}$*d.* per lb. For 15 yards the cost of each of these explosives would be, with gunpowder, £28 7*s.*; with gun-cotton, £16 12*s.*; and with dynamite, £15 9*s.* 4*d.* In every respect, including labour, dynamite had a slight advantage over gun-cotton; but each had a decided advantage over gunpowder. Mr. Nobel calculated the relative powers of nitro-glycerine, dynamite and gun-cotton to be—nitro-glycerine, 1; dynamite, 0·72; and gun-cotton, 0·69.

In an experiment made before the Gun-cotton Committee, at which he was present, a piece of iron was cut off the end of a shaft of a steam-engine; the diameter was $15\frac{3}{4}$ in., and the depth 9 in., and this was bored with a hole $1\frac{3}{8}$ in. diameter. That hole was filled with dynamite, without tamping or closing at either end, and the effect of the explosion was to rend the iron in two, and to throw the portions a distance of about 12 yards, one of the pieces being carried up a bank 12 ft. high. The power of dynamite, therefore, could not be questioned.

It was a fact beyond dispute that dynamite had been carried in Germany and in this country to a great extent—in Germany to the amount of hundreds of thousands of lbs., and for thousands of miles. In this country it had been carried in common carts hundreds of miles in large quantities, and no accident had been known to take place either in transport or storage. He produced before the Gun-cotton Committee some cartridges of dynamite which had been in his possession since 1868; and, considering the material was of a highly pasty character, it retained that character in a most remarkable degree. He could not discern the slightest difference in the appearance of the material from the time it was imported, in 1868, down to that time, 1872.

He thought that the restrictions in respect to explosives had not been instigated by the Government. The Nitro-glycerine Bill was introduced into Parliament by Mr. Alderman Lawrence, M.P., and by Mr. Graves, M.P. It was a notorious fact that nitro-glycerine in its liquid state had been imported into the city of London, and carried along the streets of Liverpool; but in this condition it was most unquestionably a dangerous article to transport, and therefore it was not unreasonable that those gentlemen should promote a Bill for the object of protecting both lives and property in the port and city of London, and in the port and town of Liverpool. That Bill was brought into Parliament late in the session, and in the month of August was re-committed in the House of Commons at 3 o'clock A.M. He wished to point out that it was partial and unreasonable in its provisions, and that gun-cotton, although more sensitive to percussion than dynamite, was not referred to in the Act, but the restrictions were confined to nitro-glycerine and dynamite. With reference to the accident which had been mentioned as having lately taken place at Wein Fawr, it did not appear to be known that the proprietors were not aware that dynamite was being used in their quarry. The foreman of the quarry, who was killed, had himself obtained the dynamite, and had used it most improperly, heating it at a cast-iron stove, in opposition to the printed instructions to the contrary.

The Paper was very fair and correct in most of its statements; but there was one point which had been omitted. Reference had been made to the quality and power, weight for weight, and to the difficulty there was with regard to gun-cotton being rigid, and not capable of being formed so as exactly to fit the bore-hole, while, on the contrary, dynamite, from its soft, plastic character, left no vacancy or interstices; but this circumstance had been lost sight of, that dynamite was much heavier than gun-cotton, so that more force was concentrated in a small space with dynamite than with gun-cotton.

The power of tutonite, which was no doubt a valuable production, was far inferior to that of dynamite. He might state, in proof of this, that when Mr. Hayward made the experiments at Carnarvon which had been referred to, there was a piece of cast-iron lying with a hole in it, weighing about $3\frac{1}{2}$ cwt. Some tutonite was put into it, and it fizzed and burnt, but the iron remained uninjured. He afterwards put a cartridge of dynamite into the same hole, and it blew the iron to atoms.

Mr. S. P. Bidder, through the Secretary, desired to make a few remarks in reference to the use of gun-cotton for blasting mines and quarries. In 1863, Messrs. Prentice brought out their patent gun-cotton, made in accordance with Baron Lenk's process. It was formed into ropes of various diameters from $\frac{7}{8}$ in. to 3 in. These were cut into pieces 6 in. long. So far as strength was concerned, this explosive worked very well.

In 1867, Professor Abel introduced compressed gun-cotton, and the demand for it was steadily increasing up to the time of the Stowmarket explosion in August, 1871. The advantages claimed for this explosive were its great power, its portability, and its safety in working.

The many severe and fatal accidents with gun-cotton could all be traced to the carelessness of workmen disregarding a few simple printed rules. They had been clearly accounted for in the official inquiries that followed; and he was not aware of any accident that could not be traced to neglect. The agent for the manufacturing interest in North Wales generally carried some compressed gun-cotton in his pocket, feeling satisfied that it would not explode if accidentally ignited.

He had recently carried out a series of experiments with gun-cotton in some coal-mines in North Staffordshire, and the result of these experiments proved that it could be used for blasting coal with great advantage. There was almost an entire absence of flame; the cartridges were portable, and could easily be divided, to suit the various thicknesses of coal to be blasted. Further experiments were made in stone-drifts with the following results, as regarded the relative efficiency of gun-cotton and gunpowder:—Gun-cotton always took the rock out to the bottom of the hole, and frequently from a lower point: gunpowder seldom broke down to the bottom, especially in very hard and jointless rocks. Again, gun-cotton was six times more powerful than gunpowder, and the blast-holes might be drilled to a greater depth and be placed further from the face of the rock; consequently a larger quantity of material could be removed without additional cost of boring. Gunpowder applied in this manner would not work unless the holes were of great diameter, to allow a sufficient quantity to be inserted. The tamping would be too short, and would probably be blown out, perhaps breaking the upper part of the hole and leaving the lower portion unbroken.

He had recently inspected several of the largest quarries in Wales, and found that gunpowder was the explosive in use without a single exception, because gun-cotton could not be obtained, although the quarry proprietors were quite willing to pay a large price for it. Dynamite was at hand, and the men had permission to fetch it from a neighbouring store, but they seldom used it. To show the confidence the men had in gun-cotton, one of the quarrymen, in reply to an inquiry, said, " When the cotton got wet, he put it in the sun to dry; but when there was no sun he took it to bed with him and slept upon it, and by the morning it was nicely dry." At the time of the Stowmarket explosion sixty quarries in Wales, employing sixteen thousand men, were supplied with gun-cotton.

Nitro-glycerine was the strongest explosive known, but the uncertainty of its action was a barrier to its employment. Several accidents had occurred in England and Wales, on the Continent, and in America, which had been destructive to life and property. It laboured under a double disadvantage, as both the full and the empty packages were dangerous to handle. He would enumerate a few instances. The explosion which took place at Newcastle, when the Mayor of the town was killed. At Mr. Darbishire's quarry near Carnarvon, a slight leakage had occurred in a sheet-iron slate truck in which nitro-glycerine, packed in tins, had been taken up. Before loading it with slates the nitro-glycerine was carefully wiped up, and some hot ashes put upon the place so wiped; but the men being still dissatisfied, before loading, retired behind a wall and threw a piece of slate into the truck, when a terrific explosion took place. A parcel of nitro-glycerine was delivered at Lord Penrhyn's quarry; one of the tins leaked, the material spreading over the bottom of the cart; on returning home the cart was blown up. An empty can, picked up by a workman at Festiniog, was taken home, under the impression that there was oil in it. It was put by the fire, but as nothing was found it was thrown under the grate, when it exploded, injuring the workman and his wife and blowing the windows out. A man at Llanberis struck an empty can with his foot; his leg was blown off. Another was killed while boring a hole at Llanberis; it was supposed that he struck some nitro-glycerine which had percolated into a crevice reopened by a previous blast. The last accident in Wales was the explosion of two carts on the high road to Llanberis, when not a vestige was found of the carts, horses, or men.

The high temperature at which nitro-glycerine froze was a great obstacle to its adoption. To overcome this difficulty, the tins containing it were first put into a pan full of hot water.

Dynamite was one of the best and least dangerous explosives now in use: it, however, laboured under the same disadvantage as nitro-glycerine—it froze at a high temperature. He was not aware of any accident that had occurred in the process of blasting, but two severe explosions had taken place in the process of warming preparatory to putting it into the blast-hole; one in a tunnel near Bristol, and the other in a slate-quarry near Carnarvon, when two men were killed.

None of the nitro-glycerine compounds could be relied upon to work with in cold weather; and the tempering or warming process must always be dangerous. Mr. Webb had mentioned that the men had no authority for using dynamite at the quarry where the explosion took place; but this could not affect the degree of safety, as all explosives must be placed in the hands of miners and quarrymen. Mr. Webb had also claimed for dynamite that more work was done in less time and for less money than could be done by gun-cotton. In some situations, for instance, when the rock was traversed by joints, and when water ran into the blast-hole, dynamite might be the more economical explosive; but when the rock was excessively hard and free from joints, it would be found that gun-cotton would be preferred by the miners, especially in underground work; and the safety and efficiency of an explosive were best proved by the extent of its use. The Welsh Slate Quarry Company used it extensively; and the manager, Mr. Chessel, had informed him that no accident had occurred for the last fifteen months; the number of men using it varying from three hundred to four hundred. The same gentleman told him that the cost of driving underground work had greatly increased since the supply of gun-cotton was stopped; and he and other quarry-managers said that the workmen, both above and under-ground, preferred gun-cotton to any other explosive. Mr. Bidder had no hesitation in stating his belief that this safe, handy, and efficient explosive would take precedence of all that had been brought before the public.

Mr. R. S. France observed, through the Secretary, that he had hitherto always considered it safe to thaw nitro-glycerine cartridges by hot water; but Major Beaumont's statement showed that these cartridges, whether of dynamite or of litho-fracteur, could explode accidentally when treated in this manner. He had accordingly given instructions for this mode of thawing to be discontinued in his quarries; and as Messrs. Lee, the Admiralty contractors for Dover Harbour, had taken all their instructions from him as to the mode of using the litho-fracteur, with which they were now deepening Dover Harbour, he had written to them not to again use the hot-water tin process, but that he would arrange some other plan; and as the men were very thickly at work in the harbour while the preparations for blasting were going on, it was possible that the discussion on the Paper might be the means of saving a considerable loss of life both at Dover and in his quarries.

Mr. J. J. Curling, R.E., through the Secretary, stated that some extensive mining operations were being carried out at Astoria, in Long Island, New York, in removing a rock that interfered with the navigation at Hell-gate. This rock was of gneiss, and was very tough and hard, numerous garnets being found in it. The following was an extract from a letter received from Lieut. Herrer, United States Engineers, who was in immediate charge of the works: "Our work commenced in October, 1869, since which time we have blasted and removed about 23,000 cubic yards of rock. The cost per cubic yard has varied considerably, say from \$10 to \$20: at present it costs about \$16. We are using nitro-glycerine at the rate of about 22 oz. to the yard of rock, and drilling almost entirely by machinery. We also find that it requires about 6 ft. of boring (holes 2 in. diameter) to produce a yard of rock. Our drilling machines each average about 3 ft. progress per hour." Lieut. Herrer had also informed him that gunpowder and gun-cotton were both tried at first, but owing to difficulty in procuring the cotton, and to nitro-glycerine being found more economical than either, that material had been alone used during the greater part of the work. It was manufactured on the spot, and the charge was contained in metallic cylinders, which exactly fitted the holes. Tamping was not required, and hitherto no accident had occurred.

Messrs. Reeves and Co., through the Secretary, stated that they were about to bring before the public a special preparation of their 'gun felt,' which had hitherto been chiefly used for sporting, in a condition suitable for engineering and mining purposes. About three years ago many successful experiments were made with it in blasting various substances; the comparative strength, weight for weight, was eight times that of gunpowder; and the question of carriage, stowage, and general safety in use were satisfactorily proved. The expense of manufacture at that time was too great to enable it to compete with gunpowder, but the article could now be produced at a much lower price. Similarly with gun-cotton, the basis of the material was pyroxilin, but the subsequent processes rendered it more regular in its action, while it was free from the liability of spontaneous combustion, or of ignition at a lower temperature than 380° or 400°.

Mr. W. W. Evans (of New York), through the Secretary, stated that he had recently received a communication from Professor George M. Mowbray, who had been engaged in the United States in making experiments in reference to explosive compounds, some particulars respecting which he thought might be interesting. Professor Mowbray's attention had principally been directed to the introduction of explosive substances into chemical combination, as distinguished from mechanical, or rather semi-mechanical admixture. He had in the first instance purchased a series of samples of the various mixtures sold in the United States as 'dualine,' and had found that it was practically impossible to manufacture them in quantities sufficiently large to ensure uniformity in their explosive properties. This defect was notable in the samples of the same article successively purchased, and it was probably owing to their complicated ingredients having been brought together with a different amount of moisture. He had also generally come to the conclusion that to mix nitro-glycerine with corn-meal, paper, pulp, rotten stone, sand, sponge, &c., diminished the explosive force of the nitro-glycerine, and occasioned a loss of power, which was unjustifiable in the present state of chemical science. In every case he found that diminution of force was not in exact proportion to the smaller quantity of nitro-glycerine contained, but that generally there was only one half of the force, and in some cases only one third the force, which the nitro-glycerine would have evolved without the admixture. Professor Mowbray stated that all these mixtures entirely changed the nature of the explosive, as when a liquid exploded, the blasting or disruptive force was exerted in an inappreciable space of time; but when the particles were separated, the peculiarity of the force of the nitro-glycerine as an explosive agent was destroyed, and it became like gunpowder, which ignited not simultaneously, but by a 'flash,' which process, though performed in a period of time practically inappreciable, was yet a complicated operation, the chemical and mechanical decomposition going on from particle to particle instead of the whole mass becoming instantaneously converted into vapour. When gunpowder was fired the following operations took place:—the sulphur ignited—the nitrate gave out oxygen—the carbon combined with the oxygen—the sulphur and potassium (by deoxydation of the potash) combined, and these processes occurred, not simultaneously, but in succession as the various particles came into the focus of heat, or under the operation of a raised temperature. In order to approximately endow gunpowder with the destructive explosiveness of nitro-glycerine, or in other words, to decompose the whole bulk instantaneously, every granule would require to be heated so that each atom would be nearly at 240°, the melting point of sulphur. Then, by further increasing the temperature, a point would be attained when the carbon or charcoal in its fine state of division—if he might so describe it—invited the nitrate to decompose; and at that instant—at which by his experiments the temperature approximated to 600°, —an explosion, that was, a conversion of every particle into gases with fulminating violence, as in the case of the ignition of nitro-glycerine, would ensue. While, on the contrary, if it was required to reduce nitro-glycerine in its effective blasting force, it would only be necessary to reduce or subject it to the conditions under which gunpowder was ordinarily fired, namely, by separating its particles, so that its fluidity was interfered with or entirely destroyed.

In the course of his experiments Professor Mowbray had arrived at the conclusion that differently constituted nitro-glycerine could be produced, possessing different congealing points; and also that temperature, as well as the presence of water in the glycerine, modified the nitro-glycerine produced. In the severe winters of the United States, he had been enabled to separate the various resulting modifications by freezing (with salt water) a mass at a very low temperature, namely, from 10° below zero to 25° below zero; and then by very slowly allowing the temperature to rise by successive stages to 32°, 38°, and 40° above zero. At the higher temperatures the nitro-glycerine presented the appearance of a granulated substance, which by gentle pressure on blotting-paper left a white mass, the paper itself absorbing an oily matter. This oily matter readily exploded by a blow, but in a congealed or solid form, the white mass could not be exploded. Having made this discovery, by using acids of suitable strength, and glycerine free from water, or nearly so, Professor Mowbray succeeded in producing an article which he had named 'Tri-nitro-glycerine.' In the first instance he had experienced great difficulty in exploding it. He found that five grains of fulminate of mercury and a vial full of gunpowder put on the top of it and covered with sand would not explode it. When cold and congealed it would not explode, and the absolute conditions of explosion seemed to be inexplicable, when finally he found that ten grains, or twelve grains of fulminate in a copper cap immersed below the surface of the liquid would explode it every time the experiment was tried.

The destructive effects of the tri-nitro-glycerine were almost incredible. With holes drilled 14 ft. deep into a heading, and charged quarter full, the rock was torn out from the bottom. It was tried at Erie Harbour in the winter of 1869–70, and by the report furnished to Professor Mowbray, it appeared that 1·6 oz. of tri-nitro-glycerine was sufficient to remove 1 cubic yard of rock at an average depth under water of 8 ft. The advantages claimed for the tri-nitro-glycerine were, that it was chemically pure, stable, and uniform; that it was difficult to explode under any circumstances, even to the extent of needing special explosive substances to ensure its ignition, and that it was free from danger by concussion, cartridges having been thrown down a distance of 40 ft., breaking the cartridges, but without exploding them.

Professor Abel said statements had been made to the effect that the Nitro-glycerine Act had been mainly introduced by Government at his instigation, and also that its action had been prohibitory, and, to a great extent, had deterred practical men from using nitro-glycerine explosives. Large dynamite works had, however, been established near Glasgow, and explosive agents of those characters had been for some considerable time extensively used in mining districts. The Act in question, and those who had contributed to its introduction, did not therefore deserve the condemnation which had been awarded to them. The Act was necessary and salutary, as had been amply demonstrated since its introduction, and, though he could not claim even an indirect share of the merit due to those who introduced it, he would take this opportunity of recording his strong conviction that its enactment had not been prejudicial to mining interests, but had been instrumental in effecting great saving of life and property.

In reference to the letter written by him to Sir John Hay, M.P., in July 1869, and used by that officer in his advocacy of the Nitro-glycerine Bill, he desired to state that he was ignorant of any intention on Sir John Hay's part to read it in the House. With the knowledge then possessed he could not have desired to have modified it in any way, had he then known it was to become a public document. He did not lay down the theory, in that letter or anywhere else, that gun-cotton was an "absolutely safe explosive," nor was there anything in the letter relating to nitro-glycerine, in the unmixed or liquid state, at variance with the statements in the Paper—although written after an interval of three years had elapsed—except the statement that nitro-glycerine was specially susceptible of explosion when in the frozen condition. He had pointed out in the Paper the reasons for the opinion, very generally entertained within the last three years, that solidified nitro-glycerine was more dangerous than the liquid—an opinion since shown to be erroneous. The fact remained, that sad accidents had repeatedly occurred with frozen nitro-glycerine, no doubt from specially reckless handling of the material, to which its apparent inertness had probably given rise. Dynamite, the only other nitro-glycerine-preparation (except Mr. Abel's glyoxilin), was known to him in 1869, and was then supplied in the form of a loose damp powder, from which the nitro-glycerine appeared to have a considerable tendency to exude. It was decidedly inferior, as regards safety, to the firm, dry, but somewhat plastic rolls, now manufactured. Continued experience and the improvements in the manufacture of nitro-glycerine had caused him to acquire, during the last three years, considerable confidence in the stability of the properly purified material, and he believed there were few scientific and practical men who had not been led, by accumulation of their knowledge and experience, and by the progress of science and industry, to modify views, recorded at one time in perfect honesty of conviction, even to a much greater extent than had been the case with him in reference to nitro-glycerine preparations.

He had listened with interest to Mr. France's narrative of the relative merits of dynamite and litho-fracteur, and of the difficulties he had experienced through dynamite being in a frozen condition, while on the same occasion the litho-fracteur was not frozen. While experiencing some surprise at the temerity with which that gentleman exercised the privilege he so warmly claimed for quarry owners of doing their best to blow their heads off, the Institution must be congratulated upon the happy escape of one of its most distinguished Members, who had assisted at the experiment described. What he believed Mr. France had really wished to promulgate by his account was, that litho-fracteur would not freeze as readily as dynamite, and that certain special chemicals introduced into the composition of litho-fracteur enabled the miner to explode it when in a frozen condition; whereas dynamite was not susceptible of explosion by the usual means under similar circumstances. An Engineer officer in the Prussian service, whom Mr. Abel had met shortly after the war, and who had been specially charged with operations of demolition in which litho-fracteur was employed by the Germans, had told him that, while in many instances it was most effective, many failures had occurred, in consequence of the material being in a frozen, and consequently inert, condition. As bearing on this point, he would also refer to an account published in 'The Times' of some experiments made at Mr. France's quarries, near Shrewsbury, with litho-fracteur, last February, in the presence of the Gun-cotton Committee. Its safety in transport and in use having been demonstrated by what appeared to him excellent practical experiments, the applicability of litho-fracteur to military operations was to be demonstrated, and, among other experiments, a stockade was to be demolished. This was intended to be effected by means of a long species of sausage stuffed with litho-fracteur. But this sausage, having been exposed to a keen wind for a few hours, had become frozen, so that at the first trial only a small portion of the charge exploded; and, though the remainder was repeatedly re-fused, it did not explode, but only burnt, without any injury to the stockade. At any rate, therefore, it appeared that dynamite and litho-fracteur were about on an equality with regard to the difficulties resulting from the freezing of the materials. It was said that improvements had recently been made in the preparation of litho-fracteur, and possibly these might to some extent diminish the difficulties referred to; still up to the present time no superiority appeared to have been satisfactorily established for litho-fracteur either in this respect, or with regard to explosive power. Such special experiments, as had been described by Mr. Nursey and another gentleman, had been carried out with equal effect both with dynamite and with gun-cotton; and it was only by systematic employment upon one and the same class of work, that the relative power of those agents could be satisfactorily established.

Pudrolythe appeared to be an old acquaintance under a new name. He had some years ago to report upon a site near Plymouth, where it was proposed to manufacture a blasting-powder, composed of spent tan mixed and impregnated with nitrate of potash, and sprinkled with sulphur. It was comparatively harmless if inflamed when exposed to the open air, but in a good blast-hole was said to do very fair work. This preparation, known as 'Kellow's powder,' was so far safe to manufacture, that the works were partly burnt down twice without explosion. It appeared to him pudrolythe was, in point of fact, this old material revived under a new name, with this difference, that a little nitrate of baryta and a little sawdust and charcoal powder were added. He would suggest to powder-makers that they might possibly make the old blasting powder compete with pudrolythe, if they were to use imperfectly burned charcoal, and either to supply the powder ingredients only roughly mixed, or to sell them separately, to be mixed as required. He really failed to discern the existence of any merit in spent tan and sawdust as constituents of a blasting powder. He must say that the statement that pudrolythe evolved no deleterious gases when exploded was to him startling in its originality.

He had hoped that the Paper would have elicited more information with regard to the practical working of explosive agents. Mr. Webb had, however, given some valuable data regarding the relative power and cost in working of powder, gun-cotton, and dynamite, which were confirmatory of the statements in the Paper, and showed that dynamite and compressed gun-cotton were about on an equality in point of power and cost. One point in the comparative value of gun-cotton and dynamite had been referred to, namely, the difference of weight of equal volumes of the two. True, dynamite was heavier than gun-cotton; on the other hand, dynamite contained 25 per cent. of inert matter; and he doubted whether it would be found that there was any difference in the weight of actual explosive material in the two substances, or any difference, favourable to dynamite, in the force exerted by equal volumes of the two materials.

The experience of Major Beaumont with regard to the work done by the violent explosives would have been instructive if that officer had given some comparative estimate of the time occupied in performing a given amount of work, as the great advantage of violent explosive agents over gunpowder, and their merits in relation to each other, existed chiefly in the saving of time of which their employment was productive. The accident with dynamite to which Major Beaumont had referred was evidently due to a spontaneous decomposition of a portion of nitro-glycerine—accidentally exposed for a long time to heat, in contact with metal—having exuded from some of the dynamite charges. The numerous fatal accidents which occurred in the thawing of dynamite, though they were doubtless ascribable in part to carelessness, must be taken as a set-off against the few accidents which had occurred in charging holes with gun-cotton, the cause of which had been fully explained by him in his Paper.[1] Similarly, the explosion at the Stowmarket gun-cotton works, the cause of which had been clearly established to possess no bearing upon the stability of gun-cotton, had more than its parallel in numerous disastrous explosions at dynamite works in Germany and America, and in the succession of explosions at gunpowder works.

It was remarkable that, notwithstanding the numerous and deplorable accidents with gunpowder, it appeared to be exempted,

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[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xxxiv., p. 338.

by special privilege, from condemnation, while the obviously unreasonable expectation appeared to be generally entertained that the manufacture and use of the violent explosives should be unattended by occasional accident. That their extensive employment, with reasonable precautions, would have the effect of greatly diminishing the accidents resulting from explosions, had already been conclusively demonstrated.

November 26, 1872.

T. HAWKSLEY, President,
in the Chair.

No. 1,349.—"On the Aba-el-Wakf Sugar Factory, Upper Egypt."
By William Anderson, M. Inst. C.E.[1]

Early in the year 1870, Mr. J. Easton, M. Inst. C.E., being in Cairo for the purpose of starting a large paper-mill which had been erected for His Highness the Khedive, was requested by His Highness to visit some of his principal sugar estates, and to draw up a report on the machinery and mode of manufacture in the sugar houses. In obedience to this request, Mr. Easton visited two factories erected by an eminent French firm, and one in which the machinery had been obtained from various houses both English and French. In all cases he found a very advanced system of manufacture was carried out on an extensive scale. Nearly white, large grain, centrifugal, machine-made sugar was produced direct from the cane-juice by the agency of animal charcoal and the usual refining process, which is expensive in Europe, but is more so in Egypt, where the animal charcoal has to be brought, for the most part, from France or England. The machinery was of excellent quality, and there was little room for improvement in carrying out the processes adopted.

Messrs. Eastons and Anderson, for a year or two previously, had been engaged in investigating and perfecting the proposition of Mr. Walter Knaggs, a Jamaica planter, for the manufacture of white sugar without charcoal filtration, by the use of sulphurous acid gas and other re-agents in defecation, and an extremely rapid method of concentration of cane-juice to sirup. Mr. Easton was

[1] The discussion upon this Paper extended over portions of three evenings, but an abstract of the whole is given consecutively.

struck with the exceptional advantages presented by the climate of Egypt for a trial of the new process, and, having satisfied His Highness of the reasonable probability of success, and, in that event, of the great economy that would arise in first cost of plant and in working expenses, obtained an order to construct the sugar factory which forms the subject of this Paper, not, however, without backing his opinions by depositing a large sum of money, to be forfeited in the event of failure. The factory was set to work early in 1872, and, at the termination of the crop, the reserved sum was punctually paid. It may, therefore, be reasonably assumed that the party chiefly interested was satisfied with the general success of the process employed.

The Aba-el-Wakf Sugar Factory, constructed specially for the sulphurous acid process, is situated on the banks of the Ibrahimia Canal, about 6 miles south of Magaga—a station on the Nile Railway, and also the site of large sugar-works—and about 2 miles west of the Nile. The distance from Cairo is about 120 miles. The Author's firm also erected and set to work, at the same time, a second sugar factory at Bene Mazar, a place about 6 miles further south. This was about half as large again as that at Aba, and arranged on the French system of defecation, using animal charcoal, so that the Author, who personally superintended the completion and starting of both factories, had special opportunities for comparing the two methods of manufacture.

To make the Paper as complete as possible, a brief sketch will be given in the first instance of the usual methods of manufacture. Cane-juice contains saccharine matter in a free state of solution. The work to be done consists, first, in cleansing the raw juice from impurities, and neutralizing its acids; and, next, in concentrating it to the crystallizing point. The main difficulty to be overcome is to prevent the crystallizable sugar existing in the juice from becoming uncrystallizable, and therefore the process which achieves the highest result in this respect most economically is the best.

Clarification is generally effected by neutralizing the organic acids of the juice by means of lime, and by removing the scum by skimming, subsidence, or filtration. Sometimes clay or whiting is added to assist mechanically in carrying down the impurities; and the operation takes place either in steam clarifiers, supplemented or not by subsiding tanks, or in the concentrating coppers. The most advanced and satisfactory system, the one adopted at Bene Mazar, and generally in Egypt, is, to heat the juice nearly to the boiling point, adding lime until its neutral point is attained. A thick scum collects on the surface, and cracks when the temperature reaches about 210°, that is to say, when incipient ebullition takes place in spots here and there. Steam is immediately shut off, and the juice is allowed to stand about forty minutes. During this time the cake of scum, which is about 2 in. thick, becomes very compact, so that, when at last the clear juice is suffered to run out through a copper strainer at the bottom of the clarifier, the impurities remain behind, and are thoroughly separated.

Bisulphite of lime is now commonly used with the same object as sulphurous acid gas. It is added in solution as soon as possible after the juice leaves the crushing rolls.

In making inferior kinds of sugar, the clarified juice is run into a battery of open pans, called 'taches,' the whole apparatus being styled a 'copper wall.' These pans are heated by direct fire under them, and the juice, as it concentrates, is ladled from one pan to the other, being skimmed all the time, and finished at last in the pan farthest away from the furnace. The whole operation is 'messy' and extravagant in fuel. An improvement on the copper wall is the 'concretor,' a shallow tray set over a furnace, down which the juice runs in a thin stream, and is rapidly concentrated; but in this apparatus, also, on account of the steam from the juice being wasted, the expenditure of fuel is very great. For the higher classes of sugar the clarified juice is run through bag filters, and afterwards through animal charcoal, or through the latter only, and concentrated in the manner above described, or by means of double-action or treble-action tubular concentrators. At Bene Mazar four sets of treble-action concentrators are used. Each set consists of three vessels. The first set is heated by the waste steam from the various steam engines. The steam evolved from the juice in these, boils the sirup in the second set of vessels, and in like manner the steam produced in the second set, boils the sirup in the last set of vessels. The first set works at about the pressure of the atmosphere, the second set at a partial vacuum of 10 inches, and the third set, like vacuum pans, under a vacuum of about 26 inches.

After concentration, and for the higher classes of sugar, the sirup, at about 22° Beaumé, is again passed through charcoal filters, and then boiled to grain in vacuum pans. Inferior sugars are struck either directly from the last 'tache' of the copper wall, or from some one of a numerous array of tubular, and other granulators, working at the ordinary atmospheric pressure.

The molasses are now almost universally separated from the crystallized sugar by means of centrifugal machines. There is great difficulty in getting the juice and sirups to pass through animal charcoal of sufficient fineness to produce much effect. The animal charcoal used by refiners, for example, is about as fine as No. 1 shot, while that used in Egypt is as coarse as hazel nuts, and even then it clogs very quickly. It appears to the Author that, until the molasses have been in a great measure separated from the crystallized sugar — which is only to be done in the curing-room—the sirups cannot be made to filter efficiently, and that, for this reason alone, it is well to avoid charcoal filtration. It is certain that juice is degraded by passing over large surfaces, as it thereby has a tendency to get sour, and thus to increase the percentage of molasses. It is hardly necessary to remark that the first cost of the charcoal, the daily waste, and the charges for fuel and labour in re-burning are serious items in the account.

The new method of sugar-making introduced at Aba will be most conveniently described in three divisions :—

1. A general description of the process of manufacture.
2. A detailed description of some of the novel machinery and appliances designed expressly for the new process.
3. An investigation into the chemistry and physics of the manufacture.

For this last branch of the Paper the Author is mainly indebted to Mr. George Ogston, analytical chemist, who made the chemical investigations for Messrs. Eastons and Anderson on juice obtained from canes sent expressly from Egypt to this country, and who, last season, visited the Aba factory, and conducted experiments on a large scale, for the purpose of determining the yield obtained from the juice, and of suggesting improvements in the chemical processes of the manufacture. It is, however, a matter of regret that, during the period of his visit, owing to the scantiness of the crop, the smallness of the canes, and the want of transport, the factory could never be worked steadily for any length of time, or to its full power. Mr. Ogston's work was thus rendered very arduous, and he was unable, from the reasons stated, to make any useful observations on the consumption of fuel.

I.—General Description of the Manufacture.

The canes are brought to the mills by railway, or by means of camels. The consumption of canes, when in full work—night and day—is upwards of 1,000 tons per twenty-four hours, so that storage for at least 600 tons—measuring 3,600 cubic yards—is required. The canes are thrown by labourers upon carriers, and are delivered into the cane-mills at the rate of about $10\frac{1}{2}$ tons per hour for each mill. This produces about 1,500 gallons of juice. The juice flows by a branch semicircular iron gutter into a main gutter, which delivers the juice of all the mills into a cast-iron raw-juice tank, falling into it through two sets of strainers.

The 'megass,' or crushed cane, is delivered from the rolls on to carriers, which take it out of the mill-room, elevating it high enough to deliver into ox-carts. In this way it is carried to the drying ground, and then spread out for several days in the sun, preparatory to being brought into the factory again as fuel.

As fast as the raw-juice tank is filled, its contents are raised by means of a centrifugal pump into the clarifiers, steam at a pressure of 60 lbs. being turned on as soon as the copper-bottoms are covered. When the juice begins to boil, it is stirred with a copper pipe, through the lower perforated end of which sulphurous acid gas is injected, and allowed to dissolve in the juice, till the colour of the latter becomes considerably lighter, and a decided separation of the flocculent matter takes place. The proper quantity of sulphurous acid to be added varies with the state of the canes and the weather, and can only be determined by practice. Approximately, a clarifier of 450 gallons would require the combustion of from $\frac{1}{10}$ lb. to $\frac{1}{2}$ lb. of sulphur.

The sulphurous acid is forced into the juice by means of a pump driven by a small independent engine, the speed of which can be adjusted to the quantity of gas required. The gas is generated by the combustion of crude sulphur in an oven, the air necessary for the purpose being sucked through by the pump; and, as the combustion depends on the supply of air, and the latter on the speed of the pump, the whole apparatus is self-adjusting.

When the factory was first started, the gas was introduced into the raw-juice tank; but it was found that the supply of juice was much too irregular to admit of the necessary accuracy being attained as to the quantity of gas injected; and the arrangement above described was adopted at Mr. Ogston's suggestion.

As soon as the boiling juice is sufficiently 'gassed,' milk of lime, mixed with China clay, is added at the rate of from $\frac{1}{2}$ gallon per clarifier to 3 gallons per clarifier, until the liquid is ascertained by the litmus paper test to be perfectly neutral. The liquid is then let down by cocks in the bottoms of clarifiers into subsiders, where it is allowed to stand till the impurities have settled down, when it is decanted by means of sliding overflows into the clarified-juice tank. After the juice is properly clarified it is perfectly clear, and about the colour of sauterne. The whole operation of clarifying and subsiding takes about $1\frac{1}{4}$ hour; the subsidence and decantation occupying about 40 minutes; hence, the twelve subsiders, having a capacity of 450 gallons each, can readily get through 8,100 gallons of juice per hour, or more than the four mills can produce.

The lime used is the ordinary produce of the native limestone; it is of good quality, and is mixed in two circular tanks, fitted with agitators. The contents of one of these tanks is allowed to subside, so as to yield clear lime water, used in washing down the cane-mills, juice-gutters, and pipes. The milk of lime from the other has a density of about 10° Beaumé, and is mixed in the proportion of $9\frac{1}{2}$ parts by weight of cold water, to 1 part of lime; an equal weight of China clay being added to assist mechanically in carrying down the impurities.

The scum which collects in the bottom of the subsiders is let out by valves, and runs down gutters to either of two tanks, from which it is filled, by means of 3-in. india-rubber hose, into linen bags placed in hydraulic presses. The juice is then separated from the solid scum. The solid scum forms about 5 per cent. of the weight of the raw juice. The clear pressed-out juice is pumped at once into the clarified-juice tank, and the solid refuse is thrown away. The subsiders are washed down by a hose at the end of each operation, the foul water being run off through wash-out valves and pipes.

The clarified juice next flows continuously through the concentrators, to which the admission is regulated so as to produce sirup of the required density, varying from 15° Beaumé to 22° Beaumé, according to circumstances. The steam generated by the concentration of the juice, is collected under a pressure of from 3 lbs. to 6 lbs., and is used for heating the vacuum pans, and for driving the vacuum pumps and centrifugal-machine engines. The juice enters the concentrators at about 160° temperature, and each particle takes about eighteen minutes to run through. The total time, therefore, between the juice leaving the mill and being reduced to sirup, is about one hour and three-quarters.

The sirup from the concentrators flows into one of four subsiding-tanks, where any impurities that may have escaped in the previous decantation are thrown down, and from which the vacuum pans suck their charges. The small amount of scum formed here is carried by hand to the scum-presses, and the clear sirup pressed out is mixed with the clarified juice. The vacuum pans are of ordinary construction, but are heated by the steam derived from concentrating the juice. They discharge their sugar into iron wagons; and, by means of railways and turn-tables, it is delivered to coolers. It is then either cured at once, while hot, in centrifugal machines, or allowed to stand some time to crystallize more perfectly. When crystallized it is passed through mixing-mills, in which it is diluted with weak molasses, and then cured, as in the previous case. The molasses whirled out from the centrifugal machines are collected in two tanks, from which the vacuum pans suck them up, re-boil them, and send them down by the wagons as second sugars into the second sugar crystallizers, where, after standing a few days, the sugar is separated by the centrifugal machines, and the molasses, boiled a third time in the vacuum pans, are sent down into a series of brick tanks, outside the factory, where the third sugars are allowed to stand during from 3 months to 6 months, and cured after crop. The molasses which finally remain—almost totally devoid of crystallizable sugar—are removed to distilleries attached to some of the older sugar factories, where they are converted into strong spirit in the usual manner.

Attached to the factory is a mechanics' shop, with lathes, planing and drilling machines, vices, and all other appliances for making casual repairs.

II.—Description of the Machinery.

Several modifications of conventional sugar machinery were made at the suggestion of His Highness the Khedive, as, for example, greatly increasing the diameter of the cane-mill rolls, abandoning the steam 'montejus' for raising the juice, and disposing the boilers so that they should be close to their work, and thereby reducing the length of the steam-pipes.

The cane mills are of exceptional size, and altogether novel in their design and construction. The Khedive considered there would be a great advantage in using much larger rolls than had hitherto been the practice, as he conceived that, with larger diameters, the nip would last longer and give the juice more time to escape from the crushed cane. Rollers of 34 in. or 36 in. diameter had been considered very large; but he proposed to try rollers of 48 in. diameter, with a proportional increase in the general strength and motive power.

In designing these mills, the Author became dissatisfied with the usual, or rather, universal mode of gearing, as it appeared to him to be so unmechanical and defective, as fully to account for the tendency cane mills exhibit of breaking down, although in crushing so soft a material as sugar-cane unusually severe strains were not to be apprehended. In the ordinary three-roller cane mill, as for instance, with rolls 36 in. diameter, the whole of the power, amounting at times to 100 I.H.P., is transmitted to the top roll shaft at about 2 revolutions per minute, and thence by means of three pinions of the same mean diameter as the rolls to the two bottom rolls. But inasmuch as the top and first bottom roll should be from $1\frac{1}{2}$ in. to 1 in. apart, and the top roll and second bottom rolls should be touching, these pinions have to be made with long teeth to admit of the above variation, and the top roll pinion necessarily works at two different depths of gear at the same time, and hence the heavy strain on the teeth is rendered doubly prejudicial. This defect may to some extent be removed—though the Author is not aware of its ever having been done—by transmitting half of the power of the engine through the top roll shaft to the opposite side of the mill, and then driving one pair of rolls by pinions of suitable diameter; but this would not materially reduce the pressure on the teeth, or on the bearings due to that pressure, or lessen the immense strain on the connecting shaft and coupling which drives the top roll. The mills made for the Aba factory were designed to obviate the preceding defects (Plate 3). The rolls are 48 in. diameter by 5 ft. 6 in. long, staked by means of eight keys at each end, on to 18 in. wrought-iron shafts, the keys being arranged so as to 'hit and miss' on opposite ends, so that they can be readily driven in or out without taking out the rolls. They are not in any way secured against working out. Staked by four keys on the ends of the roll shafts outside the mill frames are spur wheels, each nearly twice the diameter of the rolls. The spur wheels of the two lower rolls being on the same side, and passing each other, are actuated by a double-shrouded pinion, keyed on to a second motion shaft, which passes under the bed-plate of the mill, and carries, at its opposite end, an internal geared wheel 11 ft. 9 in. diameter. The top roll spur wheel is on the opposite side of the mill to the wheels of the bottom rolls, and is actuated by a shrouded pinion keyed on a short second motion shaft, one end of which has a journal in a bracket bolted to the mill frame, and the other revolves in a pedestal fixed to a massive A frame, and carries, overhung, a spur wheel of the same diameter and pitch as the internal wheel on the lower second motion shaft. The outer end of the crank shaft of the steam engine is carried in a pedestal resting on the bottom of the A frame, and by means of separate pinions keyed on it, engages into the upper spur and the lower annular wheel. The effect of this arrangement is, 1st, that the power of the engine is divided over two pinions, having, together, 18 in. of face, a greater width than could usefully be given to one pinion gearing into one wheel. 2nd, the second motion shafts distribute the power through three pinions, having, together, 38 in. of face, and, owing to the large diameter of the roll spur wheels, traveling nearly twice as fast as the peripheries of the rolls, and, on that account, having to endure only half the pressure on the teeth and journals that would have arisen under the old system of gear; and 3rd, the large diameter of the roll-wheels allows three teeth to be in gear at one time instead of only one. In order to permit of a variation in the distance apart of the rolls, without affecting the accuracy of the gearing, the brasses which carry the two lower roll-shafts are arranged to slide upon their seats in a direction nearly at right angles to the lines of centres of their spur-wheels and the pinions they engage into; and these brasses, instead of being kept up to their work by the points of large set screws in the usual fashion, are supported over their entire width by quoins or inclined planes drawn up by pairs of bolts passing through the top distance pieces closing up the gaps in the side frames, the angle at which these gaps lie offering also the contingent, but not inconsiderable, advantage of enabling the bottom rolls to be taken out without interfering with the top roll. The caps of the top rolls are held down by 6 in. bolts passing completely through the side frames and base plate, under which they are cottered without the intervention of the usual layer of timber or other elastic material, so that there is no possibility of yielding, however severe the strain. As the design was carried out, confidence in its superiority to the common plan increased; and although the erection of the factory at Bene Mazar was ordered before the Aba Mills had been completed and tried, no hesitation was felt in applying the same strength of gear to rolls 48 in. diameter and 6 ft. 6 in. long, and, as the event proves, with good reason, for both sizes have worked without the smallest difficulty or accident throughout the last season.

It will be noticed that the spur wheel driving the first lower roll is considerably overhung, but this is not objectionable, because the power required in the first squeeze of the canes is very much less than that expended in the final pressing, which circumstance compensates for the overhang, the shafts being of equal diameters.

To illustrate more clearly the advantages derived from the new system of gearing, the pressures on the various moving parts have been worked out and arranged in the following table :—

TABLE showing the PRESSURES on TEETH and JOURNALS of CANE MILLS with Rolls 4 Ft. Diameter, worked by an Engine indicating 100 H.P. at 30 Revolutions, to give 18·3 Ft. speed of Roll Surface per Minute.

Old System.					New System.				
—	Number of Revolutions per Minute.	Speed of Pitch Line in Feet per Minute.	Load on each Tooth in Contact per Inch of Face in lbs.	Pressure on nearest Journal in lbs.	—	Number of Revolutions per Minute.	Speed of Pitch Line in Feet per Minute.	Load on each Tooth in Contact per Inch of Face in lbs.	Pressure on nearest Journal in lbs.
Crank shaft pinion .	30·00	210·0	557	15,000	For top roll gear .	30·00	188	414	9,000
					For lower ditto . .	30·00	188	414	
Spur wheel in gear with ditto . . .	6·64	210·0	557	1,500	For top roll gear .	5·08	188	414	20,000
					For lower ditto .	5·08	188	414	7,000
Second motion pinion	6·64	72·0	1,223	21,000	For top roll gear .	5·08	36	1,309	29,000
					Double pinion for lower roll ditto .	5·08	36	764	27,000
Spur wheel in gear with ditto . . .	1·46	72·0	1,223	12,000	For top roll gear .	1·46	36	1,309	13,000
					For cane ditto ditto.	1·46	36	764	35,000
					For megass ditto ditto	1.46	36	764	15,000
Mill pinions on top roll.	1·46	18·3	1,906	50,000 sideways	Mill pinions. Not represented in New System.				
Ditto on cane ditto .	1·46	18·3	1,906	51,000					
Ditto on megass ditto	1·46	18·3	1,906	25,000					

The large wheels and rolls, as already stated, have all been staked on with four or eight keys, and not bored and turned as is the usual practice among London engineers. The Author believes that with heavy gearing, much more trustworthy work can be done in the former manner. It also offers great facilities in erection and subsequent repairs. The arrangements for lubrication were carefully considered, each of the 16 in. roll journals, besides their oil syphons, had pipes connected to the water main permanently fitted, but water was very seldom required, and that only to the top roll journals, which, from the bearing being upwards against the cap, were not so readily reached by the oil. It is difficult to estimate the pressure exerted by the top roll, but as its journals became occasionally slightly warm, it may be conjectured, that the limit of 1,200 lbs. per square inch was reached; and in that case, the area on the diameter of the two journals being 576 square inches, the pressure would be at least 300 tons, the four main cap bolts, 5 in. diameter under the threads, being competent to carry a working load of 390 tons.

It seems pretty generally agreed, that 18 ft. per minute is the most advantageous speed for the surface of mill rolls, but the Author has frequently seen these mills run at double that speed, and, apparently, doing equally efficient work. The cane-carriers are driven by spur gear through clutches from the front bottom rolls, and the megass carriers by belts from the top second motion shafts. No experiments have as yet been made on the percentage of juice squeezed out, but when evenly fed, the megass comes out very dry, and on chewing it only a faint taste of sugar is perceptible.

As, in the new process of manufacture adopted at the Aba factory, no use can be made of exhaust steam, except perhaps in heating the juice on its way to the clarifiers—a practice of doubtful expediency—the engines used for driving the cane mills are, contrary to the usual practice, condensing with double cylinders; the smaller ones being $18\frac{1}{2}$ in. diameter, 3 ft. $1\frac{1}{2}$ in. stroke, working under 60 lbs. steam; and the larger ones 29 in. diameter, and 4 ft. 6 in. stroke. Steam is admitted by ordinary slide valves fitted with link-reversing motions. The beams, connecting rods, and cranks, are of wrought iron, each engine being completely self-contained on a massive bed-plate carrying a heavy entablature on six columns.

Steam to the cane mill engines is supplied by four internally fired coal burning Cornish multitubular boilers, each 20 ft. $2\frac{1}{2}$ in. long, and 6 ft. 6 in. diameter, having two flues 14 ft. $6\frac{3}{4}$ in. long, and 2 ft. 6 in. diameter, and 74 tubes 3 in. diameter, and 5 ft. $7\frac{3}{4}$ in. long, making in all 675 square feet of available heating surface, and 30 square feet of fire-grate. A similar boiler to these, in use at the Erith Ironworks, has been found to evaporate 48·15 cubic feet of water per hour, from a temperature of 101°, with a consumption of 8·78 lbs. of Newcastle coal per pound of water. It was found that one boiler well fired would keep two cane mills working at full speed, and as the coal was of similar quality, it is presumable that about the same rate of evaporation was maintained. This would give, at 22 lbs. of steam to the indicated horse power per hour, about 135 I.H.P. for two mills, the actual indicator diagrams showing 136 horse power.

The boilers are fed from the hot wells of the engines by duplicate donkey pumps, the waste steam from which is condensed in heating the feed water. A 15-ton traveling crane runs the whole length of the cane-mill house, and commands every part of the engines and mills. It may be noted, incidentally, that the new system of gearing is very much more compact, and will fit into a less space than the old.

The juice from the cane mills is carried by 7-in. semicircular spouts to a 12-in. semicircular gutter, running at a slight slopo the whole length of the mill, and delivering the juice into a cast-iron tank holding about 600 gallons. The gutters are raised above the floor, and although a little inconvenient to persons moving about the mill-house, are very accessible and easily kept clean, both internally and externally. The juice tank is fitted with two sets of strainers, the upper one having about 4 meshes to the inch, and the lower one 60 meshes to the inch, both disposed so that the solid matters arrested by them are easily raked off by means of scrapers with long handles and india-rubber edges.

Inside the mill, and under the clarifier stage, are two 5-in. centrifugal pumps, duplicates of each other, each worked by a separate pair of engines, having cylinders $4\frac{1}{4}$ in. diameter, 10-in. stroke, and communicating their motion to the fan spindles by internal annular gear. The pumps are placed sufficiently low to require no charging, and either set is put in motion by turning on steam by a starting handle on the clarifier stage. The juice is conveyed from the pumps to the clarifiers, under the stage, by a 5-in. copper pipe, furnished with a branch fitted with a swiveling head and sluice valve to each pair of clarifiers. The raw juice tank is provided with a float, and an index in the clarifier room, by which the sugar-boilers can see when there is juice enough to fill a clarifier. When there is sufficient juice they start one of the pumps, which fills it in about 1½ minute, the juice running in a solid, steady stream, showing no indications of that churning which is supposed to be so objectionable. There is great misapprehension as to the action of a centrifugal pump—wrongly so called—on fluids. When the blades are properly curved no churning takes place, but a perfectly uniform and almost radial flow is maintained through the fan. The Author is convinced that the centrifugal pump is the best means of raising cane-juice or sirup. It was adopted at the suggestion of the Khedive, who greatly disliked, and with reason, the steam 'montejus' in general use; for not only are they inaccessible and uncleanly, but owing to the admixture of condensed steam, they seriously dilute the liquor raised. The clarifiers, 6 ft. 6½ in. diameter, and 2 ft. 6 in. deep, up to the skimming lip, hold an actual working charge of 450 gallons of cold juice. They consist of copper pans 1 ft. 6 in. deep, bolted into cast-iron steam jackets, and surmounted by galvanized iron cylinders, 1 ft. 6 in. deep, in which skimming overflows, 2 ft. wide, are formed. The heating surface of each is 52·58 square feet. Steam at 60 lbs. pressure is admitted by 2½-in. valves, and the condensed steam is taken off by self-acting traps, one to each clarifier. The juice is let out by 4-in. cocks, worked by levers placed beyond the hand-rail over the subsiders; and ½-in. pet cocks to ascertain the state of the steam jacket, and let out any air, complete the equipment.

Steam is turned on as soon as the copper bottoms are covered; and the juice, usually at a temperature of 72° when pumped in, begins to boil in about twenty minutes, and is kept boiling about five minutes. A small portion of the impurities floats on the surface, and is skimmed off at the lips provided for the purpose, whence the skimmings flow by suitable shoots to the tanks which receive the rest of the scum.

The mean of three experiments on the power of these clarifiers in heating water to the boiling point give the following results:—

Mean duration of experiments	24 minutes.
Mean initial temperature of water	67° F.
Mean steam pressure	42·1 lbs. 289° F.
Mean weight condensed steam	742 lbs.
Mean weight of water heated	4,558 lbs.

		Lbs.		
Units of heat in condensed steam	. . .	742 × 990 =		734,580
Heat spent in heating copper	. .	840 lbs. × 145 × 0·095 =	11,571	
,, ,, ,,	cast iron .	2,828 lbs. × 145 × ·129 =	52,900	
,, ,, ,,	wrought iron	567 lbs. × 145 × ·113 =	9,200	
,, ,, ,,	water. .	4,558 lbs. × 145 =	660,910	
			——	734,671

Units of heat per square foot per difference of 1° per hour in heating water	210·2
Loss in heating clarifier, by radiation, &c., &c. . . .	11·1 per cent.

In some other experiments with a clarifier of similar construction, but of only 12 gallons capacity, the trials were carried further and the rate of boiling was ascertained as well, both for water and sirup, the latter being a solution of 9 lbs. of molasses and 4 lbs. of sugar in 90 lbs. of water, equal to juice at about 8° Beaumé. The results were:—

	Water.	Juice.
Units of heat per square foot per difference of 1° per hour, heating	260	219
,, ,, ,, ,, ,, evaporating	606	521

as usual, in both water and juice, heat was transferred about $2\frac{1}{3}$ times more quickly in boiling than in heating, no doubt in consequence of the greatly more rapid circulation; and in both operations the addition of $14\frac{1}{2}$ per cent. of sugar seems to have reduced the efficiency of the surface by about 15 per cent.

The subsiders, twelve in number, corresponding to the clarifiers, are plain cast-iron tanks, 6 ft. square and 2 ft. 6 in. deep, with outside flanges and angles rounded to a 4-in. radius for facility in cleaning. Each tank is fitted with a brass 5-in. Appold overflow, actuated by a quick-threaded screw and hand-wheel for the purpose of decanting the clear juice, which is discharged into a wrought-iron tank running across the mill under all the subsiders; while for letting off the scum, and for the subsequent washing, two 3-in. brass plugs are provided connected, the one to the scum gutters, and the other to the waste water-pipes. The clarified juice takes about half an hour to subside, the china clay added with the lime assisting mechanically in carrying down the impurities. Hydrants with 1-in. india-rubber hose, and brass nozzles and cocks, are provided for washing out the clarifier and subsiders, and for sluicing the stages.

Sulphurous acid gas is generated in a cast-iron D-shaped muffle, 5 ft. long, and 12 in. wide. A small grate under it allows the hearth to be heated in order to start the combustion of the raw sulphur; and the admission of air is regulated by a sliding cover closing up one end of the retort. The raw sulphur is introduced through a small door in the end cover by a scoop 1 in. wide, similar in form to those used for charging gas retorts. About 62 ft. of 3-in. cast-iron cooling pipe provided with numerous cleaning doors for removing any flowers of sulphur that might distil, conduct the gas to two duplicate double-acting pumps having cylinders of 12 in. diameter and 12 in. stroke. These are worked by belts with fast and loose pulleys from a counter-shaft actuated by a 4-horse oscillating donkey engine, which is also used for driving the mechanics' shop when the factory is not at work, but during crop is used exclusively for the gas pumps, the speed of which is thus easily regulated. The pumps are entirely of iron with india-rubber flap valves, and they appear to stand very well against the action of the sulphurous acid.

From the pumps the gas is led into a receiver containing about 114 cubic feet, or 144 times the capacity of one pump, and from thence it is carried by a 3-in. main under the clarifier stage, a 1-in. copper branch rising between each pair of clarifiers, and terminating in a cock and india-rubber hose fitted with a copper stirring pipe, the extreme end of which is finely perforated, to allow of a uniform distribution of the gas through the body of juice in the clarifier. A loaded valve permits the escape of any excess of gas clear of the roof.

The greatest quantity of sulphur used is $\frac{1}{4}$ lb. to a clarifier of 450 gallons of juice, or 5 cwt. of sugar. Oxygen does not alter its volume in combining with sulphur to form sulphurous acid; the latter gas measures 5·9 cubic feet to $\frac{1}{2}$ lb. of sulphur, the combustion of which therefore results in $29\frac{1}{2}$ cubic feet of mixed sulphurous acid and nitrogen gases, to which must be added at least as much excess of air, or, say 59 cubic feet in all, at a temperature of 60°. The factory, in full work, ought to yield 14 clarifiers per hour, for which $3\frac{1}{2}$ lbs. of sulphur are required, producing 413 cubic feet of gas, or rather, 475 cubic feet at 150°, which is about the temperature at which it reaches the pumps; hence about 6 revolutions per minute will deliver all that is required. The pumps were purposely made of large dimensions, as the quantity of gas necessary had not been certainly determined at the time the factory was designed.

The skimmings from the clarifiers, and the scum from the subsiders are run into two circular wrought-iron tanks, fitted at their lower ends with 3-in. cocks and india-rubber hose, by means of which the two hydraulic presses are charged. These consist of cast-iron boxes 4 ft. square, 12 in. deep, surmounted by inverted cylinders 18 in. diameter and 2-ft. stroke, with 12-in. trunks, the lower ends of which carry the upper pressing tables. The scum is run into linen bags, about 12 in. wide and 5 ft. long, ranged in 3 layers or 4 layers, with galvanized-iron gratings between each layer. As each bag is filled, its mouth is twisted up and laid back over itself. When the charge is complete, the water pressure—derived from the ordinary supply of the factory, under a head of 45 feet—is turned on by a common slide valve forming part of the cylinder of each press, and the moderate pressure of $2\frac{1}{4}$ tons on an area of 16 square feet thus obtained is sufficient to express all the juice. The juice runs into a small tank, from which it is immediately pumped by a donkey engine into the clarified-juice tank under the subsiders. When the scum is sufficiently dry, the slide valve is reversed, and the upper table raised to permit the bags to be taken out and emptied of the solid residuum. This part of the process was very imperfectly worked last season. It was supposed that this scum, like that obtained from ordinary clarification, would readily drain through coarse cloth, and a battery of filters was prepared accordingly, with one hydraulic press to finish the drained refuse. The addition of china clay, however, completely changed the nature of the scum, converting it into a puddle, which retained the juice obstinately until subjected to a moderate pressure. The one hydraulic press proved insufficient for the new method which had to be adopted, and so a large portion of juice had to be thrown away with the scum. In extenuation of this failure it may be pleaded that in our colonies, and, it is believed, in those of other countries, the scum is generally run into the distillery together with the molasses, so that comparatively little attention has been paid to perfecting machinery for separating juice from scum, and no one, certainly, had any previous experience as to the proper mode of treating the residue of this new process of defecation.

The clear juice, when it has gradually fallen to about 160° temperature, is run into the concentrators. These are five in number, each consisting of a copper tray 23 ft. long by 6 ft. wide, heated by a steam boiler beneath, and forming part of it, and covered by a sheet-iron casing which confines the steam evolved from the juice.

The steam boiler works under 60 lbs. pressure, and is the same size as the tray and $12\frac{1}{2}$ in. deep, the lower side being flat, like the tray, and connected to it by screwed stays spaced 6 in. pitch. From the bottom plate hang 204 water tubes, $3\frac{1}{4}$ in. diameter and 1 ft. 6 in. long, and 263 tubes of the same diameter but 4 ft. long, each tube having inside it a cast-iron circulating pipe. The boiler is set over a furnace, the door of which is flush with the floor of the stokehole, and fitted with a sliding plate to regulate the admission of the megass with which the opening is supposed to be kept constantly stuffed. The original fire-grate was 9 ft. long by 6 ft. wide, arranged so that it could be fixed on two different levels according as it was used for coal or megass, but it was found much too large for the latter fuel; indeed, up to the present time, no satisfactory grate has been contrived in Egypt to burn it, and experiments are now in progress to determine this important point. The ash-pit is very deep and communicates with a tunnel, which runs quite across the factory, serving as the air-shaft for the supply of all the megass burning boilers, and as the road by which their ashes can be removed without interfering with the stoking above or causing risk of fire to the heap of fuel collected in the stoke space.

The heating surface of the copper tray is increased by 495 vertical nozzles screwed into it; these nozzles are of brass, cast very thin and slightly tapered. Their mean external diameter is 2⅛ in., and they project 4½ in. above the plate. The sheet-iron cover is 3 ft. 8 in. high at the crown, semi-cylindrical in form, the ends also being of the same curve. It is surmounted by a steam dome 2 ft. diameter and 5 ft. high, from which issues a 9-in. steam-pipe governed by a slide stop-valve. Two 2¾-in. pipes rise from the copper plate, and, passing through the sheet-iron cover, terminate in 4-in. lever safety-valves, which permit the escape of excess steam from the boiler. Two 6-in. safety-valves placed on the top of the dome perform the same office for the steam evolved from the juice. Three 5-in. plate-glass peep holes, and a wash-out valve and cock are also fitted to the juice tray, while the boiler is furnished with two glass gauges, a pressure-gauge, and a blow-out cock and pipe. To supply the small loss of water in the boilers through accidental leakage of the safety-valves, a duplicate pair of small donkey pumps are provided. The clarified juice is brought from the trough under the subsiders by a 5-in. copper pipe to a similar trough carried on pillars across the entire face of the concentrators, a 2½-in. pipe descends to each and admits the juice, by a brass cock with a graduated dial, into small cast-iron cisterns—fitted with a glass gauge for ascertaining the level of the juice—from which it flows through a brass pipe having three branches into the tray. At the opposite end the sirup flows through a similar pipe into a second cast-iron regulating vessel also fitted with a glass gauge, and thence through a 2-in. brass bib-cock with graduated dial, into a small open cast-iron cistern having an overflow keeping the sirup within 2 in. of the top, and fitted with a large gilt Beaumé hydrometer floating in a cage, and arranged to point to a small staff fixed to any desired degree of density; so that the illiterate Arabs attending the trays have merely to keep the density such that the upper end of the hydrometer shall float fair with the top of the fixed staff. The sirup overflowing from these cisterns runs into a copper main, by which it is distributed into either of four tanks, each holding 2,500 gallons, where it is allowed to subside before being drawn up into the vacuum pans. Supposing the factory were in full work, producing 6,000 gallons of juice per hour, and this were concentrated to 21° Beaumé, it would be reduced to 43 per cent. of its volume, or 2,580 gallons per hour; hence the tanks would allow about 3 hours for subsidence; which appears to be sufficient to permit any solid impurities that may have escaped in decantation from the juice subsiders, or may have been formed by coagulation in the trays, to precipitate.

The suction pipes of the vacuum pans dip into the tanks to within about 1 in. from the bottom, the scum that remains is drawn off by suitable plugs and carried, as already stated, to the scum presses, where the expressed sirup mixes with the clarified juice and so passes again through the trays. In watching the working of the concentrators through the peep holes, the surface of the juice, while rising to the boiling point, appears quite calm for about $\frac{1}{5}$th of the length nearest the inlet; it then begins to simmer, and finally to boil violently. If the juice is in good order it makes very little foam, but if not properly tempered a thick froth soon forms, but appears to condense against the cover and drop back into the boiling fluid. Each particle of juice takes about 18 minutes to pass through the tray, and although exposed to the temperature due to 3 lbs. or 4 lbs. pressure of steam on its surface, the sirup appears to gain very little colour—hardly more than would be due to the increased density.

The steam generated from the juice is collected into an 18-in. wrought-iron main, and taken thence by one 12-in. branch to the vacuum pans, and by another to the vacuum pumps and centrifugal engines, which it actuates, supplying thus all the power necessary for boiling to grain, curing, driving the mechanics' shop, and raising the water required throughout the mill.

One of these concentrators was set up at the Erith Ironworks, and tested as to its evaporating powers. The heating surface of the steam generator or boiler amounted to 1,276 square feet, composed of 1,138 square feet of vertical tube and 138 square feet of horizontal surface.

The juice tray contained 325 square feet of surface, composed of 187 square feet of vertical nozzle and 138 square feet of horizontal surface.

The mean of two experiments of an hour's duration each gave:—

Mean pressure in generator	47 lbs.	= 294° F.
„ „ tray	5·8	= 228° F.

Temperature of water fed in	$62\frac{1}{2}$° F.
Gallons of water run in per hour	1,160
" " run out per hour, at 212° . . .	247
Gallons per hour evaporated from $62\frac{1}{2}$°	913
Coals consumed per hour	952 lbs.

Raising 247 gallons of water from $62\frac{1}{2}$° to 228°, is equivalent to evaporating 42 gallons from the boiling point; hence the duty done appears to have been equivalent to evaporating 921 gallons of water per hour from 62°, or nearly 148 H.P. To raise the water from $62\frac{1}{2}$° to 160°, the temperature at which the juice flows into the concentrator, is equivalent to evaporating 110 gallons from 160° at 5·8 lbs. pressure; hence the power of the tray appears to have been equal to the evaporation of 1,023 gallons from 160° temperature.

In concentrating juice from 10° Beaumé, the volume is reduced to 43 per cent.; hence each tray should be competent to concentrate 2,379 gallons of juice per hour at 160° from 10° Beaumé to 21° Beaumé, or three trays should be competent to do the work of the entire factory. In actual work, however, this result is very much modified, partly by the accumulation of soot on the tubes of the generator, partly on account of the increased amount of heating surface in the trays necessary to evaporate sirup, and partly from the thin film of incrustation that soon forms over the surfaces of the trays when the clarification is carelessly done. Unfortunately, during Mr. Ogston's experiments, the trays had been at work already four or five weeks without cleaning, and megass was being used as fuel, so that he could make no satisfactory trial of the rate of evaporation attained with juice under the ordinary working conditions.

In some experiments made at Erith to assist in proportioning the trays, it was found that similar surfaces transmitted per difference of 1° of temperature per square foot per hour in heating to the boiling point 368 units, and in evaporating 660 units, or 1·8 times as much. Assuming these relations to hold in the trays, the mean result of the experiments shows that 271 units are transmitted in heating and 491 units in evaporating per difference of 1° of temperature per square foot per hour. That 2 square feet of evaporating surface are required in the tray per horse power; and also that 55 square feet are occupied in heating, while 270 square feet are occupied in evaporating. In the generator 8·6 square feet of gross heating surface per horse power is required, or nearly 4 times as much as in the tray. It was feared that the vertical water tubes would become coated with soot, and require sweeping from time to time, but, at the end of the season's working, they were reported comparatively clean. Internally there was no fear of incrustation, as the water in the generators is never changed, and, for this reason, this form of boiler is very suitable for a concentrator. It will be noticed that the experimental tray gives a much higher duty than the actual concentrator; this is accounted for by the circumstance that the model was supplied with unlimited steam from the factory boilers, while in the actual tray the generator was evidently unequal to the work; but this want of balance was expressly made to provide for the deterioration of the trays from incrustation. The mean weight of fuel consumed was 952 lbs., being at the rate of 6·43 lbs. per cubic foot of water evaporated in the trays.

In case of steam being required in the vacuum pans and low-pressure engines when the concentrators are not in use, as would be the case at the finish of the crop, and in working over the third sugars, a connection is made between the low pressure steam main and the boilers supplying the clarifiers, and to guard against over-pressure, as well as to provide for the escape of excess steam from the concentrators, a 6-in. pipe is carried up from the 18-in. steam main through the roof, and closed by a 6-in. safety valve, capable of being relieved by a hand-wheel from below.

The boilers supplying steam at 60 lbs. pressure to the clarifiers, juice, and sulphur pumps, centrifugal machines, and feed-donkeys, are 4 in number. They are externally fired, 28 ft. 8 in. long, 6 ft. 6 in. diameter, each with two 2 ft. 6 in. flues, each flue being fitted with eight Galloway tubes. Each boiler has in all 600 square feet of effective heating surface, and is equal to 50 H.P. The total work to be performed is about 178 H.P., but besides the margin of 22 H.P. supplied, it was intended to make use of the surplus steam from the cane-mill boilers whenever megass ran short, these boilers being adapted expressly for coal, while the others have grates specially suited for megass.

They are fed by a duplicate pair of donkey-pumps, which draw their supply from a cast-iron tank, into which all the water condensed in the clarifiers runs, and is supplemented by a supply from the water-tower admitted through a ball-cock.

There are five copper vacuum pans, each 10 ft. diameter and 9 ft. 6 in. deep, having 65 square feet of heating surface in the double bottom, and 295 square feet in the four 4-in. coils. Beyond their unusually large size, there is nothing remarkable in their construction. The charges sent down to the coolers measure about 370 cubic feet and weigh $14\frac{1}{2}$ tons. The pans usually work under a vacuum of 27 inches, and draw their injection direct from a supply-well inside the curing-house. Although steam of only 3 lbs. pressure is used, and the heating surface is by no means large in proportion to the contents of the pans, they yet boil violently, and get through their work in a very satisfactory manner. Each pan is connected by copper pipes to both the sirup and molasses tanks, so that either material can be boiled in any pan.

The vacuum pumps (Plate 4) are 4 in number, 28 in. diameter and 1 ft. $10\frac{1}{2}$ in. stroke, making 30 strokes per minute. They have ordinary india-rubber valves playing on grids in the buckets, and brass flap foot-valves. From each pump a 9-in. pipe rises with a regular slope of 1 in 50, and runs along under the vacuum pans, the whole four pipes being so disposed that two pumps, or either of them, may be connected to any one pan, the connections being made by 9-in. sluice cocks suitably arranged. It is very important in wet air-pumps to lay the vacuum pipes on a regular slope, so that the injection water should not lodge anywhere and seal up the exit for air and uncondensed vapours. One pump is amply sufficient for one pan, but the power of connecting a second pump is very useful as a security against accidents. A 1-in. injection pipe and cock is fitted to each pump, for the purpose of charging it and getting up the vacuum at starting.

The pumps are worked directly from the beams of a pair of engines having cylinders 29 in. diameter and 5 ft. stroke, and their own condenser air-pumps, 13 in. diameter and 3 ft. $5\frac{3}{4}$ in. stroke. As the steam used is at only 3 lbs. pressure, the valve-ports are made very large, and there is a provision for blowing through, so as to establish a vacuum in the condensers before starting.

The engines driving the centrifugal machines are of exactly the same construction and size, but, instead of the vacuum pumps, have a pair of bucket and plunger double-acting pumps, $4\frac{1}{2}$ in. and $6\frac{1}{2}$ in. diameter and 1 ft. $10\frac{1}{2}$ in. stroke for the high service water supply, and, instead of the plain fly-wheel, a spur fly gearing into a mortice pinion keyed on the main lay shaft, which, running below the floor level, actuates the centrifugal curing machines and the mechanics' shop.

The vacuum engines have indicated 28 H.P. when in full work, the centrifugal machine engines 80 H.P. Both sets are much larger than needed, but under the peculiar circumstances it was thought prudent to allow a sufficient margin in estimating the horse power which would probably be required.

Warnings of prejudicial consequences were freely indulged in as to the probable result of this attempt to use steam generated from cane-juice in driving steam engines; nothing worse, however, has occurred than a shyness at starting when the pressure of steam has not been quite 3 lbs. The Author had an opportunity of drawing one of the pistons after the factory had been at work a month, but could detect no unusual appearance; and, since the end of the season, all the cylinders and valves have been overhauled, with a like result.

There are 24 centrifugal curing machines fixed in a line, nearly down the middle of the curing-house. These are divided into 4 groups of 6 machines, each group being driven under the floor by half-cross belts from a countershaft common to 6 machines. On it are loose driving-pulleys, set in motion by wood-lined cones engaging into iron ones sliding on feathers in the shaft, and thrown in or out by clutch-levers actuated by hand-gear fixed to the casings of the machines above.

The countershafts are driven by belts from the main lay shaft actuated by the steam-engine, so that any group of centrifugal machines and its countershaft can be readily stopped altogether. The space under the floor where the belts and countershafts are placed is lofty and well lighted, and the gearing can be attended to without interference with the sugar-making above, where only the casings of the machines appear. These are 3 ft. 2 in. diameter, and 2 ft. $1\frac{1}{2}$ in. high; the baskets are 30 in. diameter, and 11 in. deep; the outsides made of galvanized corrugated iron, lined with finely-perforated copper. They revolve 1,200 times a minute, and produce between 70 lbs. and 80 lbs. of dry sugar at each charge. From 4 charges to 5 charges are easily worked off in each hour. For steaming the sugar and cleaning the baskets, perforated copper pipes are introduced, both inside and outside, and connected with a steam-main running under the floor beneath the casings.

Under the vacuum-pans is a railway, terminating at each end in a 13-ft. wagon turntable, which meets also a line of rails running down the curing-house, and passing out by a gate to the third boilings' molasses tanks outside the factory. Two iron wagons each of 370 cubic feet capacity, with sloping bottoms, and fitted with two screw discharging-sluices, receive the sugar from the vacuum pans, and are moved by means of hand-gear attached to one pair of wheels, either to the first boilings' crystallizers, 9 in number, 18 ft. 8 in. long, 9 ft. 8 in. broad, 2 ft. 2 in. deep, on one side of the curing-house, or to the second boilings' crystallizers, 10 in number, 18 ft. 8 in. long, 6 ft. 8 in. broad, 3 ft. 4 in. deep, on the opposite side, or, finally, to the third boilings' molasses-tanks outside the factory.

The sugar from the first boilings is usually cured hot, but four mixing-mills are provided, being driven by belts from the counter-shafts of the centrifugal machines, and used for mixing up the sugar, when it becomes too stiff to cure, with weak sirup before it is put into the centrifugal machines.

All the tanks, for containing sugar in various stages, are made of cast-iron plates, with planed joints and external flanges; the angles being rounded to a 4-in. radius, so that they present, internally, perfectly smooth surfaces, free from angles, and therefore easily cleaned.

Throughout the factory, water mains, with hydrants and india-rubber hose, are laid for the purpose of washing down, and as precaution against fire.

The Aba factory has an extreme length over all of 481 ft. 6 in., by an extreme width of 155 ft. The buildings consist of a wrought-iron skeleton, composed of columns of girder-section, 12 in. deep, spaced 20 ft. from centre to centre, and supporting arched lattice roof-girders, across which are secured Z-shaped purlins, to which the galvanized corrugated roof is fixed.

The space between the wall-columns is filled in with 12-in. brickwork; iron sashes, with semicircular tops 10 ft. high and 4 ft. wide, being built in where required. All the doors and gates have wrought-iron frames, sheeted with corrugated iron.

The roof rafters are made very substantially in order to enable tackle to be hung from them for lifting the machinery, the lattice webs giving great facility for placing timbers from rafter to rafter for this purpose.

In the cane-mill house is a 15-ton traveling-crane, running on wrought-iron rail-girders, supported overhead by brackets from the wall-columns; and a 4-ton traveler is fitted up in a similar way, to command the mechanics' shop and the vacuum and centrifugal machine engines.

The following are the dimensions of the several buildings :—

	Length.	Breadth.	Height.	
	Ft.	Ft.	Ft.	In.
Cane-mill house	220	33	25	6
Main building	260	94	35	0
Mechanics' shop annex	260	30	25	0
Warehouse annex	160	30	25	0

The preceding dimensions are from centre to centre of the walls, and from the floor to the underside of the crown of the roof rafters.

The total area covered, measured over all, is 45,162 square feet.

The water-supply is derived from the Ibrahimia canal, which runs within 200 yards of the factory. The condensing-engines and vacuum-pans draw their injection-water direct from the service wells, while the water necessary for washing down, for miscellaneous use, and for supplying the cane locomotives, is raised by means of the pair of pumps, attached to the engines of the centrifugal machines, into a cast-iron tank, containing 14,000 gallons, fixed on the top of a tower 42 ft. high. On the ground-level of the tower there are a pair of duplicate 4-horse engines, actuating three throw-pumps, intended to provide water when the factory is not at work.

Not far from the main buildings are the gas-works, constructed to supply 300 lights.

III.—The Chemistry and Physics of the Manufacture.

The property of sulphurous acid gas, or of salts containing that gas, such as the bisulphite of lime, in preventing or arresting fermentation, and in bleaching vegetable substances, is well known. It seems to have been applied to the manufacture of sugar from cane-juice as early as 1838, when Mr. E. Stolle took out a patent for discolouring saccharine matter by sulphurous acid gas instead of animal charcoal; and subsequent patents have been taken out in 1849, 1850, 1857, and 1862, for similar purposes.

But it does not appear that any marked success has attended the use of the gas, though it is incomparably cheaper than the bisulphite of lime, which at present is largely employed in the British West India colonies. It may be that the latter substance finds favour on account of its not requiring special apparatus for its application; but the Author is inclined to think that sulphurous acid gas has failed from two causes. In the first place, it has to be applied quite as carefully as the lime used in ordinary tempering. Being extremely soluble, juice will take it up to the extent of 33 times its own volume; and hence a great excess is easily and imperceptibly added, only to require neutralizing again by lime, which forms sulphite and bisulphite of lime; the latter being wholly soluble in the weak cane-juice, but is, in part, changed, at the expense of the atmosphere, into the sulphate, which, although soluble in about 450 volumes of hot water, is deposited rapidly on the surfaces of the concentrators and vacuum-pans, rendering them inefficient, and extravagant in fuel. In the second place, the gas has always been tried at existing factories, most probably, with very defective and slow concentration; hence the juice, which, if quickly concentrated—not, however, in vessels heated by direct fire, as in 'taches' and concretors—would have made white sugar, has been degraded till all the benefits of the gas are lost. The Aba factory, it is believed, is the only one ever built expressly for the use of sulphurous acid, and hence the success which was immediately attained.

In the simple clarification with lime, great care should be taken to add the exact quantity necessary to neutralize the organic acids in the juice. The salts of lime then formed—chiefly acetate—are all soluble, and are not deposited if concentration follows rapidly; but if there is an excess of lime, or long exposure to the air, the carbonate is formed at the expense of the atmosphere, and becomes very troublesome. At Bene Mazar, last crop, the clarification was constantly under European supervision, and so carefully done that, at the end of the season, there was no deposit whatever, either in the triple-action tubular concentrators or the vacuum pans; and, as excellent white sugar was made, it is presumable that the correct quantity of milk of lime was used. This varied between $1\frac{1}{4}$ gallon to $2\frac{1}{2}$ gallons, at 10° Beaumé, corresponding to from $1\frac{1}{3}$ lb. to $2\frac{2}{3}$ lbs. of caustic lime, or say, an average of 2 lbs. of caustic lime per clarifier of 353 gallons.

At Aba, during Mr. Ogston's experiments, $\frac{1}{2}$ lb. of sulphur was actually consumed for 450 gallons of juice; but this quantity, in consequence of the imperfect arrangements for 'gassing' already explained, was greatly in excess of what was necessary for clarification. Laboratory experiments seem to indicate that about $\frac{1}{10}$ lb. per 450 gallons will be sufficient. The lime required to neutralize this will be nearly the same weight, and therefore will form but 4 per cent. of the lime necessary for tempering in the ordinary manner; that is to say, 4 per cent. more lime will be required by the sulphurous acid process than by the ordinary method of defecation; and this is probably little, if any, more than the sirup, as it leaves the concentrators, will be able to retain in solution. The lime required at Aba, if used in the same proportion to the juice as at Bene Mazar, would be $2\frac{5}{10}$ lbs. per clarifier, increased only to $2\frac{6}{10}$ lbs. in neutralizing the sulphurous acid gas; it is therefore expected that the deposit of sulphate of lime, which materially interfered with the working of the concentrators last season, will be very considerably reduced, if not completely removed; more especially because they are not in a condition analogous to steam boilers out of which only steam is taken; on the contrary, from them at least 40 per cent. of the entering fluid flows out again, and must carry a large proportion of slightly soluble and suspended matters with it.

The rapidity of the process of getting the juice to the state of sirup, when it is safe from fermentation, is best illustrated by comparison with Bene Mazar. In that mill a particle of juice in traveling through the apparatus remains—two hours in the juice tank and clarifiers—two hours in the charcoal filters—an hour and three-quarters in the triple-action concentrators—in all five hours and three-quarters; while at Aba, as has been already shown, the same state is reached in less than two hours, or in about one-third the time.

It is well known that sulphuric acid is a deadly enemy to crystallizable sugar, and sulphurous acid being very nearly allied, it was feared that its use might also be to some extent prejudicial. To settle this point, samples of juice obtained from Egyptian cane were carefully clarified in the ordinary manner with lime, and then filtered through charcoal, and also by the sulphurous acid gas process; the resulting specimens of clarified juice were then analysed, and it was found that the samples obtained from the latter process were to a slight extent richer in crystallizable sugar; the difference, however, was very small; so that, practically, it became safe to assume that there would be no loss of crystallized sugar through the use of sulphurous acid.

Inasmuch as the third boiling of molasses has to stand from 3 months to 6 months before it can throw down all the crystallizable sugar, a complete investigation into the yield of any process is a very tedious business, and, in fact, can only be accurately done by exact observation throughout the season's working, extending, with the manufacture of all the produce, over at least seven months or eight months. Nor is it possible to make any satisfactory estimate of the yield of the third boiling, as it varies very much, depending greatly on the state of the canes and the goodness of the original clarification and concentration of the juice. Mr. Ogston devoted one month to watching the successive transformations of 164,345 gallons of raw juice as far as the third boiling; and, considering the immense number of measurements taken, the corrections for temperature necessary, and the circumstance that a large number of observers had to be employed, the results of his investigations are surprisingly accurate.

The yield of 164,345 gallons of raw juice, at $9\frac{3}{4}°$ Beaumé and 72° Fahrenheit, was :—

	Tons.	Cwts.	Qrs.	Lbs.
First white sugar	54	18	2	18
Second boiling brown	18	6	3	1
Third „ estimated	9	3	1	14
All sugar—total	82	8	3	5
Molasses after second sugars	24	12	2	25

or, at the rate of 1·124 lb. per gallon, the white sugar alone being 0·75 lb. per gallon. At Bene Mazar the yield of first sugars was 0·71 lb. per gallon; the total yield being estimated at 1·21 lb. per gallon.

At either factory the result must be looked upon as extremely good, considering that the canes were very small, their dimensions seldom exceeding 4 ft. long by 1 in. to $1\frac{1}{2}$ in. diameter. A great number of the canes were also so short that they had to be carried up to the mills in baskets. And, besides this, they lay frequently for two weeks and even three weeks cut before they were ground. During the experiments, a lot of cane sent from Bene Mazar, where it had been cut down to make room for the Agricultural Railway, lay a fortnight before it was crushed. Sugar-makers can readily estimate the deterioration of the juice which resulted from this delay.

The Author is indebted to the courtesy of the Colonial Company for the following statement:—On their estate in Demerara—famous for the richness of its sugar-cane—from cane-juice, when at its best in the months of March, April, and May, and indicating 10° Beaumé at 70° temperature, they obtained, of first white sugars 8·43 per cent. on the cane-juice, and of second sugars 4·56 per cent., or in all 12·99 per cent., or about 1·405 lb. per gallon.

The company does not work the molasses a third time, but as the second boiling forms 54 per cent. of the first, it is probable that very little crystallizable sugar is lost. At Aba, the second boiling forms only 33 per cent. of the first, and it is not likely that the sugar derived from the third boiling would make the aggregate amount greater than 50 per cent. This result seems to show that, under like favourable circumstances, equally high results may be looked for in Egypt.

Sir Daniel Cooper, Bart., late Speaker of the Legislative Assembly of New South Wales, who is extensively interested in the sugar industry of that colony, has kindly communicated the following information respecting the yield of two sugar factories on the Clarence river. Of first yellow sugars they made in 1871, 0·89 lb. and 1·01 lb. per gallon of juice respectively; of second sugars, 0·29 lb. and 0·14 lb. and of molasses, 0·57 lb. and 0·47 lb. In these mills concretors are employed for the concentration; and as no use whatever is made of the steam from the juice, more than 2 tons of coal has been consumed per ton of dry sugars, besides all the megass.

The quantity of molasses, or uncrystallizable sugar remaining after the first boiling may be taken as the measure of the degradation the juice has suffered during its manufacture into sugar. Taking the percentages in each case on the first and second sugars together, it appears that the Aba factory makes but 33 per cent.—Bene Mazar, 55 per cent.—the Australian mills, 41 per cent. and 48 per cent. respectively—and the Colonial Company, 47 per cent. This seems to demonstrate that the sulphurous acid gas process, when combined with rapid concentration, realizes a larger percentage of marketable sugar than any other system of manufacture; and this result will become still more apparent by an inspection of the following table of produce by different mills, from which it will be seen that the Aba Factory also yields the highest percentage of first white sugar:—

—	Egypt.		West Indies.	New South Wales.	
	Aba.	Bene Mazar.	Colonial Company.	Chatsworth.	Southgate.
First sugar, white	56·1	43·6	43·6		
Ditto ditto, yellow	.. ..	.. ..	.. ..	50·8	62·5
Second ditto	18·7	20·8	23·6	16·5	8·4
Molasses and third sugar	25·2	35·6	32·8	32·7	29·1
	100·	100·	100·	100·	100·
Percentage of Molasses on first and second sugars	33·7	55·3	47·6	48·6	41·4

The total yield of all sugars and molasses, in pounds per gallon, was 1·325 at Aba; 1·62 and 1·75 in the Australian factories; and 2·19 in Demerara: showing that the Author's statements about the bad condition of the Egyptian canes is fully borne out.

The specific gravity of cane-juice is affected not only by the saccharine matter it contains, but also by the various impurities in solution, and even by solid matters in suspension. The density of juice is generally taken by Beaumé's hydrometer, and as an illustration of the manner in which suspended matter affects its indications, it may be mentioned that milk of lime at 70° temperature, as long as it is kept agitated, will indicate 10° Beaumé when mixed in the proportion of 10 parts by weight of water to 1 part of lime, but, when suffered to subside, will register only 2° in the clear solution containing 1 part of lime in 700 parts of water.

Throughout Mr. Ogston's experiments the density of the juice and sirups was carefully ascertained, and he found, on comparing the actual yield of sugar with the tabular quantities represented by the density of the juice, that there was a total loss of 5·91 per cent.; and between the quantity contained in the juice entering the concentrators, and that held by the sirups running out, a loss of 1·62 per cent. These results, though valuable as indicating that no great error had been committed in the numerous measurements, cannot be taken as strictly true, because the readings of the hydrometers were undoubtedly affected by the lime, and its sulphate was proved to have been held in solution by the deposits both in the concentrators and in the vacuum pans.

The information obtainable as to the manner in which the densities of saccharine solutions are affected by temperature, and the changes of volume which take place in concentration being very scanty, experiments were instituted to determine these points accurately. It was found that at all densities a range of 4° Beaumé corresponded to a variation of 122° of temperature, and that the law of variation in density due to change of temperature is the same as in water. The alterations of volume caused by concentration also followed closely those calculated from the specific gravity. Diagrams of curves illustrating these important points are attached to this Paper (Plate 5).

Crystals, separating from impure solutions, are always purer than the mother-liquors; hence the dark yellow mass sent down from the vacuum pans, when drained from the uncrystallizable sugar and water associated with it, leaves a crystalline mass more or less white behind. This separation, technically called 'curing,' may be performed by simple draining in vessels of suitable form, or, as in refineries, in moulds of the familiar sugar-loaf shape, aided by suction; but on sugar estates it is generally done in centrifugal machines. When the sirup is good, the white crystals may be separated without washing of any kind, but generally from a pint to a gallon of water or weak molasses is thrown into each charge, to assist in washing the surfaces of the crystals; or, the same object may be attained, by projecting a jet of high pressure steam against the inside of the revolving ring of sugar; the steam, condensing, washes away the molasses and at the same time heats the mass and makes it dry more quickly when spread out afterwards on the mixing floor. Yellow sugars are frequently the pure crystals coated with more or less molasses, and therefore when considering the relative yield of different factories, it is necessary to know the quality of first sugars produced, as the loss, in washing yellow sugars white, amounts to between 10 per cent.

and 30 per cent. of their weight. Dry white sugar runs like sand, but yellow has a peculiar 'cling' in it, due to the stickiness of the molasses. The most difficult variety to produce is the bright canary-coloured sugar, which can only be obtained from very pure bright sirups.

The mother-liquor, separated from the first sugar, contains a considerable quantity of crystallizable matter which separates again, as in all crystallizing operations, by second concentration, and yields the second sugars, which it is generally most profitable to leave in the yellow state. The same remarks apply to third and fourth boilings.

The Author has been able, with the assistance of the data obtained at every step of the manufacture, to calculate the degree of concentration necessary in the trays to supply sufficient steam for the vacuum pans and steam engines, and then to calculate the probable consumption of fuel per ton of sugar. By means of the indicator diagrams (Plate 5), it has been ascertained that the vacuum and centrifugal engines work at 108 collective I.H.P., and as they do not work expansively, and there must be considerable loss from condensation in the large steam-pipes, they probably consume 50 lbs. of steam at 3 lbs. pressure per I.H.P. per hour. To supply these engines, therefore, would involve the evaporation of 541 gallons of water per hour in the concentrators.

Supposing the factory to be in full work, each mill producing 1,500 gallons of juice, that is, 6,000 gallons per hour at 10° Beaumé collectively, the yield of all sugars at the ascertained rate would be 6,744 lbs. per hour.

From Mr. Ogston's observations, it appears that the water to be evaporated in boiling down the second and third sugars—including 1 gallon of water added to each centrifugal charge—amounts to 60 per cent. of the weight of the totally finished sugars, or to 405 gallons per hour, to which must be added 10 per cent., or 40 gallons for loss by radiation, &c. 6,000 gallons of raw juice at 72° temperature, when clear of its scum and reduced in volume by 5 minutes' boiling in the clarifiers, would become 5,476 gallons of clarified juice sent down to the concentrators at 72° temperature, and would contain 11,700 lbs. absolute sugar, which, at the specific gravity of 1·6, would measure 731 gallons. It was ascertained that, in the first sugars sent down to the coolers, the saccharine matter was associated with water amounting to 30·4 per cent. on the yield of all sugars, or 205 gallons per hour.

In this manner (541 + 405 + 40 + 731 + 205) 1,922 gallons of the juice have been disposed of, leaving 3,554 gallons to be evaporated, one part in the vacuum pan being at the expense of the steam raised from the other in the concentrators. Allowing 10 per cent. on the total amounts for loss and waste, the quantity should be divided in the proportion of 60 per cent. to 40 per cent., leaving thus 1,422 gallons to be evaporated in the vacuum pans by 2,132 gallons, converted into steam in the trays. There is then in the sirup ready for the trays:—

	Gallons.	Gallons.
Saccharine matter	731	
Water associated with first boiling	205	
Water evaporated in vacuum pan	1,422	
Total sirup	——	2,358
Water evaporated in concentrators to produce power, and boil second and third sugars	986	
Water evaporated to boil first sugar	2,132	
Total evaporated in trays	——	3,118
Total clarified juice per hour		5,476

The sirup, therefore, will form 43 per cent. of the clarified juice, and if the latter gauges 10° Beaumé the former would indicate 21° Beaumé. Comparing this with the observations, it appears that 153,341 gallons of clarified juice were converted into 72,049 gallons of sirup, both at 160°, the latter being 47 per cent. of the former; or if the juice stood at 10° Beaumé the sirup would have indicated 19° Beaumé, that is, rather less steam was actually generated in the trays than the foregoing calculations indicate, which is accounted for by the third boilings not having been made during the experiments, and, therefore, that much less steam was required by the vacuum pans.

These calculations agreeing so well with observations, make it probable that the latter were very accurate, and point to the result, that by utilising the steam from the concentrators, the evaporation of 57 per cent. of the juice only is necessary to convert the whole into sugar and the residuary molasses.

For the third boilings, quiet and uniformity of temperature are necessary. As they have to remain crystallizing from three months to six months, a large provision of tanks is required. These seem to answer best when built of masonry and plastered with native cement. The third boilings form about 1½ per cent. of the raw juice; hence, in a factory working ninety days, at the rate of 6,000 gallons an hour, tanks to accommodate 194,400 gallons would be required.

The total horse power required to work the Aba Factory, assuming that a cubic foot of water at 62° Fahrenheit evaporated at 212° represents a horse power of boiler duty, is computed as follows:—

	H.P.
The four cane mill engines take 68 I.H.P. each. Allowing 25 lbs. of steam per H. P. per hour, which will cover loss by steam-pipes, &c., they will require of boiler power. . . .	112·0
The clarifiers have to heat 6,000 gallons of juice per hour, from 72° to 212°, and to boil for five minutes, and will absorb . .	163·5
The concentrators having to raise 5,473 gallons of juice from 160° to 230°, and to evaporate 3,118 gallons under 3 lbs. pressure, will take	519·0
Steam under 60 lbs. pressure used in steaming centrifugals, calculated	11·2
Sulphurous acid pumps, calculated	1·5
Donkey feed pumps, ,, ...	2·3
Total H.P. = Cubic feet of water to evaporate from 62° F. = ...	809·5

or nearly 11 H.P. per ton of sugar per 24 hours. If 8 lbs. of coal are necessary to evaporate a cubic foot of water from 62°, then 6,476 lbs. of coal would be necessary to produce 6,744 lbs. of sugar, or the weight of coal will be 96 per cent. of that of the produce in sugars.

Supposing the cane mills to express 68 per cent. of juice, the 6,000 gallons per hour would produce 30,325 lbs. of wet megass. From experiments made on a large scale by Mr. Black, the resident engineer of the Magaga Sugar Factory, it appears that dry megass, fit for burning, weighs 53 per cent. of the wet; and he found that 29,578 lbs. of dry megass did as much as 16,000 lbs. of ordinary north country coal, or that it required 1·85 lb. of megass to do the same work as 1 lb. of coal. The canes yielding 6,000 gallons of juice, therefore, produced 16,072 lbs. of dry megass, which consumed in the evaporation of 809·5 cubic feet of water gives nearly 20 lbs. of megass to the cubic foot. According to Mr. Black, 14·8 lbs. should be enough; but an imperfect experiment, made on a small Cornish boiler at Magaga, gave only 3·06 lbs. of water per 1 lb. of megass, or 20·7 lbs. to the cubic foot. As an approximation Mr. Black considers that 1 lb. of coal is equal to 2 lbs. of megass, or 16 lbs. of megass to the cubic foot of water, so that there seems to be margin enough to warrant the statement, that the refuse of the canes should give fuel enough to make the sugar; and this would especially be the case in Egypt, where the climate is favourable to drying the megass.

In addition to the megass, most of the Egyptian mills are said to consume 1 ton of coal per 1 ton of sugar, but the true statistics are difficult to arrive at. The Author believes that in some of the factories in the West Indies the consumption of coal has been reduced to a ¼ of a ton per ton of sugar; but this is in addition to the megass, and triple-action concentrators are in use. The quantity of extra fuel required in any case depends upon the percentage of juice pressed out. From Mr. Black's experiments at Magaga, dry megass appears to contain 10 per cent. of moisture. Payen gives the composition of Otaheite cane at maturity as: water 71 per cent., sugar 18 per cent., and ligneous and other matters 11 per cent.; consequently the composition of dry megass may be assumed for different degrees of pressing to be as follows:—

Percentage of juice pressed out	60·0	70·0	80·0
Water dried out of megass	21·1	13·6	5·7
Water left in dry megass	1·9	1·6	1·5
Sugar ditto ditto	6·0	3·8	1·8
Ligneous matter, &c., ditto ditto	11·0	11·0	11·0
	100·0	100·0	100·0
Percentage of sugar and ligneous matter, on juice	28·3	21·1	17·3

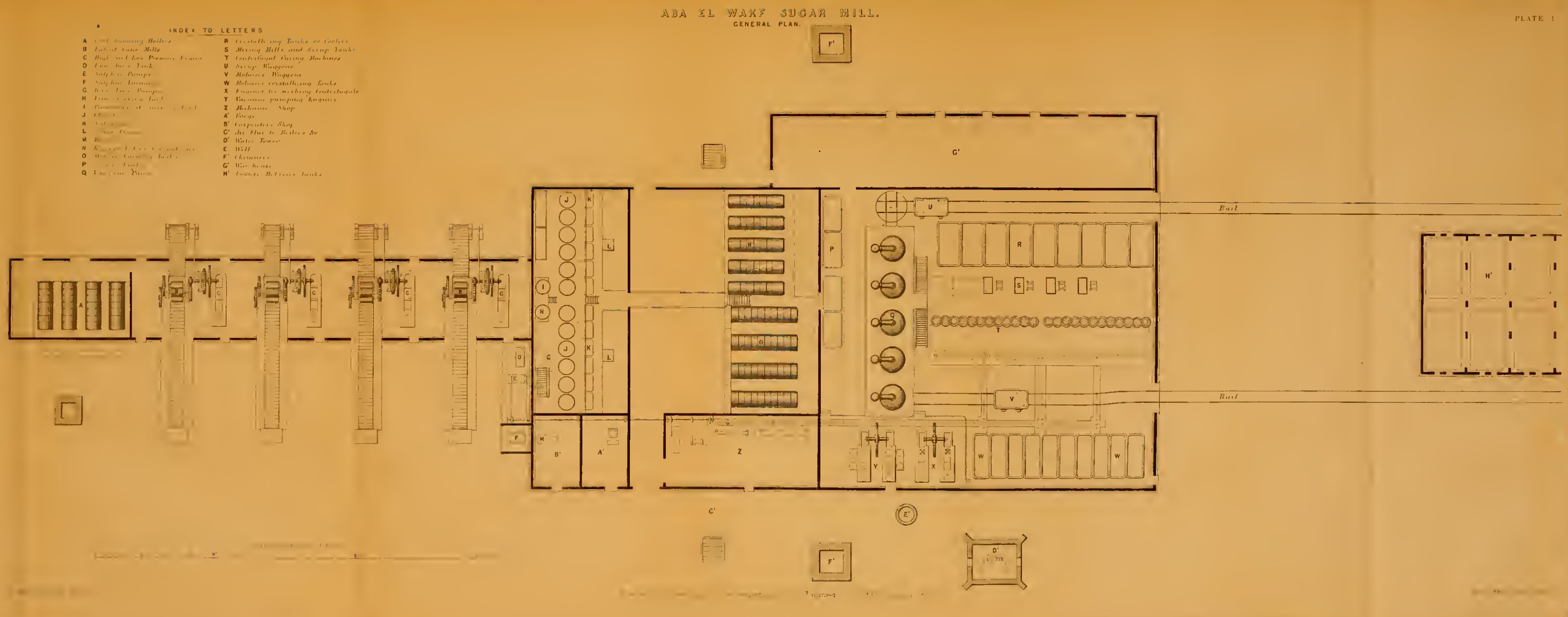
The last set of figures shows how rapidly the fuel available decreases with the increased yield of the cane mills. It has been already stated that Mr. Ogston was unable to ascertain the consumption of fuel. In such great factories as that at Aba, when worked only to about a quarter of their power, great loss arises from condensation in long and large steam pipes, as well as from frequent stoppages for want of cane, and from the nature of the case, a really trustworthy return could only be obtained from records kept during the whole crop. The megass being spread out to dry over many acres of land, it is difficult to bring it in with the necessary regularity, so that observations taken only from day to day, would most likely be deceptive. The Aba mill, however, was run some days by burning megass only, but no record exists as to how the stock of megass which was in course of drying was affected.

The cost of the machinery, iron buildings, and roofs of the Aba factory in England, including also the animal charcoal filters and re-burning apparatus, which were supplied as a measure of precaution, but never erected, was £90,000. The cost of the Bene Mazar factory for machinery and iron buildings was £130,000. Correcting the cost of the Aba factory, so as to bring it up to the same powers of production as Bene Mazar factory—but deducting the cost of the charcoal apparatus—the amount would be £100,000; thus showing an economy in favour of the sulphurous acid gas over the animal charcoal process, in producing white sugar, of £30,000 on the capital account, in addition to a saving of £14,000 for the first year, and £7,500 per annum afterwards, in animal charcoal, and labour and fuel in using it. The Aba factory was ordered in April, 1870, and the whole was made and shipped before the April following. The Bene Mazar factory was ordered in December, 1870, and was all shipped by the following November, and during the same time the Malatea factory, as large as Bene Mazar, but which was not to be erected till a season later, was constructed and completed; so that in the space of nineteen months, machinery to the value of nearly £400,000 was designed, constructed, and shipped. The erections on the spot were completed with great rapidity, especially when the obstructions of climate and carriage are considered, and the difficulties about straw to burn bricks and lime. In conclusion, the Author thinks that the large yield of first sugar, the small percentage of molasses, the calculations as to fuel, and the economy of first cost and working, justify the opinion that the sulphurous acid process offers a reasonable prospect of success to those who may employ it. It has been widely stated, however, that the white sugar produced will lose colour materially if kept in bulk. No evidence has, as yet, reached the Author on this point, and he can therefore only state the opinion of many chemists, that there does not seem to be any ground for the apprehension.

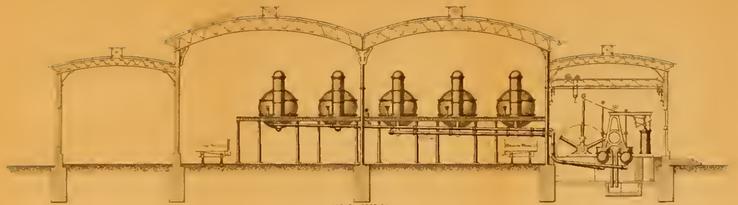
The Author has to express his acknowledgment for the gracious manner in which His Highness the Khedive granted permission for the preparation of this Paper, and ordered all official records to be placed at his disposal. The Author's thanks are also due to Mr. H. C. Anderson, Assoc. Inst. C.E., chief engineer in charge of the sugar factories of Aba, Bene Mazar, and Malatea, under whom they were erected and put to work in an extremely short time, and to Mr. F. Cheesman, Stud. Inst. C.E., the resident engineer of Aba, who was more immediately responsible for its erection and working.

The Paper is illustrated by a series of drawings and diagrams, from which Plates 1, 2, 3, 4, and 5, have been compiled.

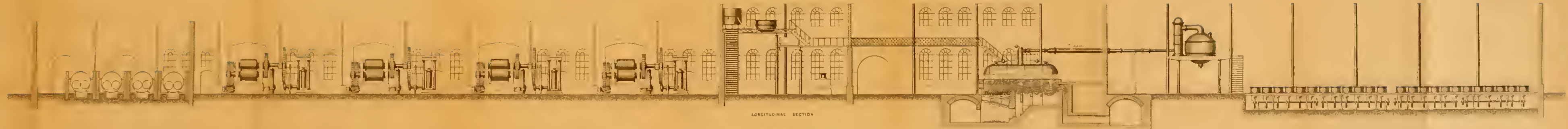
Mr. Anderson


ABA EL WAKF SUGAR MILL.
GENERAL PLAN.
PLATE 1
INDEX TO LETTERS
B Patent Cane Mills
C High and Low Pressure Engine
E Sulphur Pumps
R Crystallising Tanks or Coolers
S Mixing Mills and Syrup Tanks
T Centrifugal Curing Machines
U Syrup Waggons
V Molasses Waggons
W Molasses crystallising Tanks
X Engines for working Centrifugals
Y Vacuum pumping Engines
Z Machine Shop
A' Forge
B' Carpenters Shop
C' Air Flue to Boilers &c
D' Water Tower
E' Well
F' Chimneys
Rail
Rail

ABA EL WAKF SUGAR MILL.



CROSS SECTION

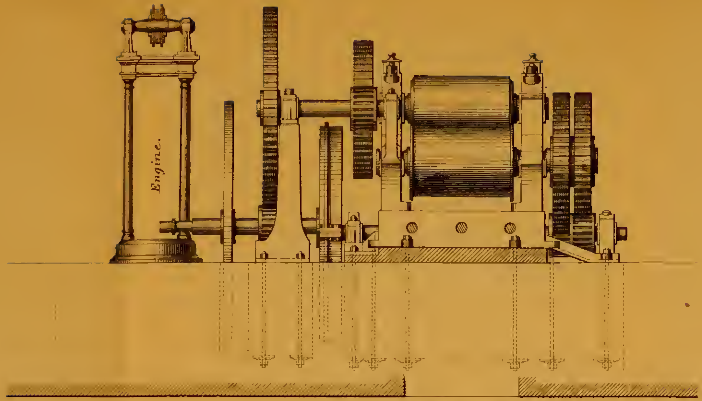


LONGITUDINAL SECTION

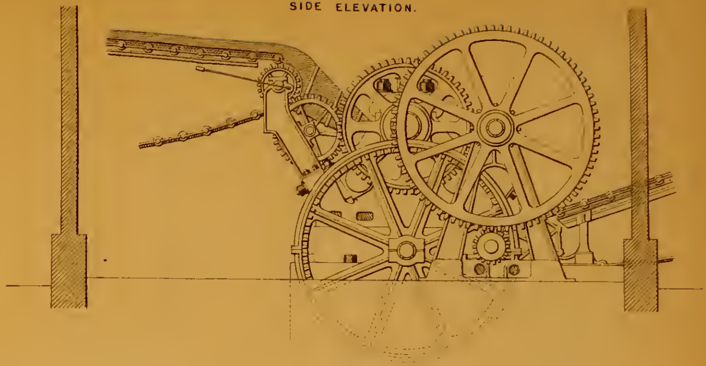
ABA EL WAKF SUGAR MILL.

CANE CRUSHING MACHINE.

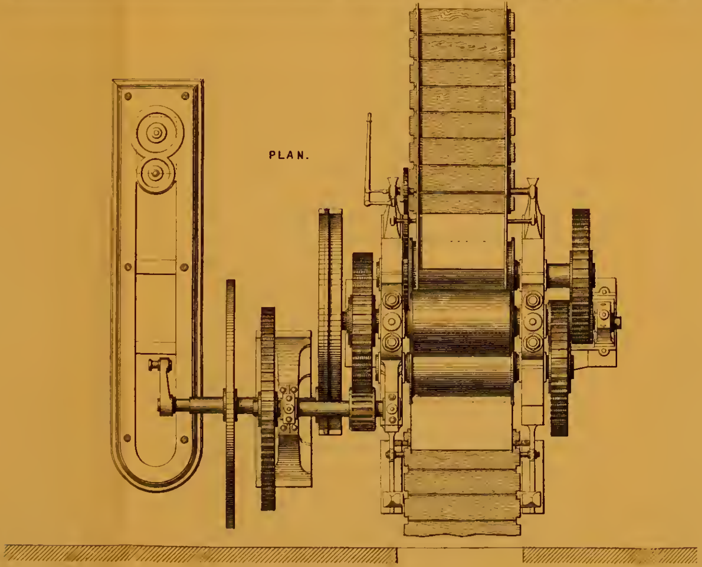
FRONT ELEVATION.



SIDE ELEVATION.



PLAN.



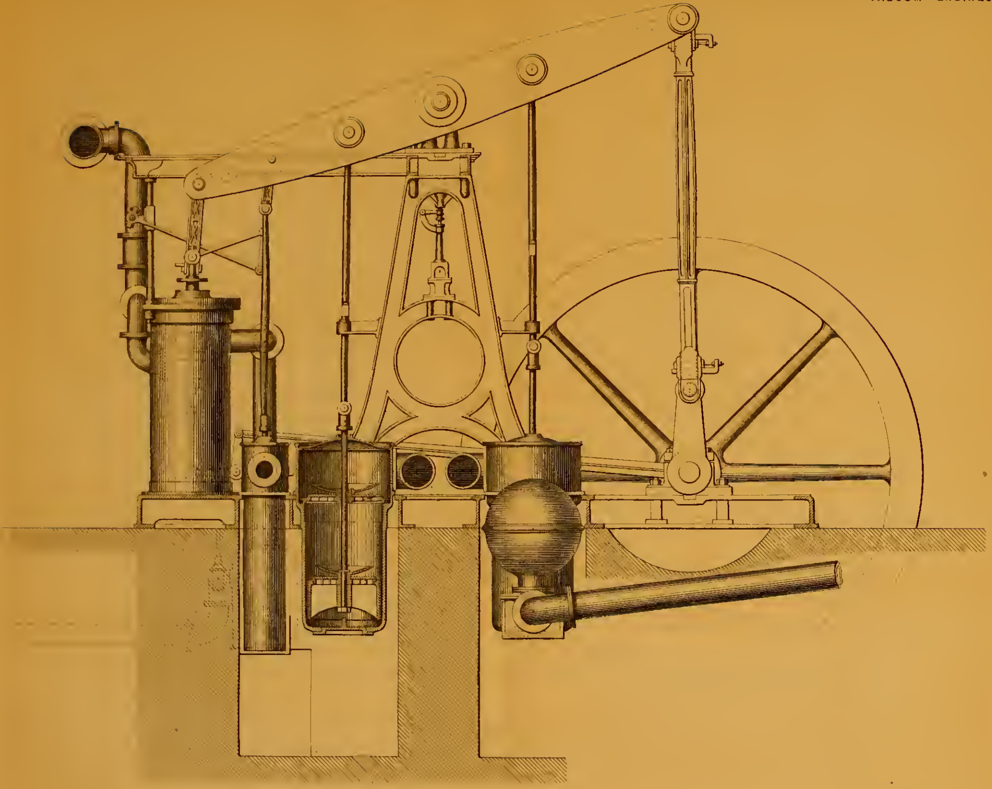
DETAIL OF BEARING.

Scale 1/8 Inch — 1 Foot.

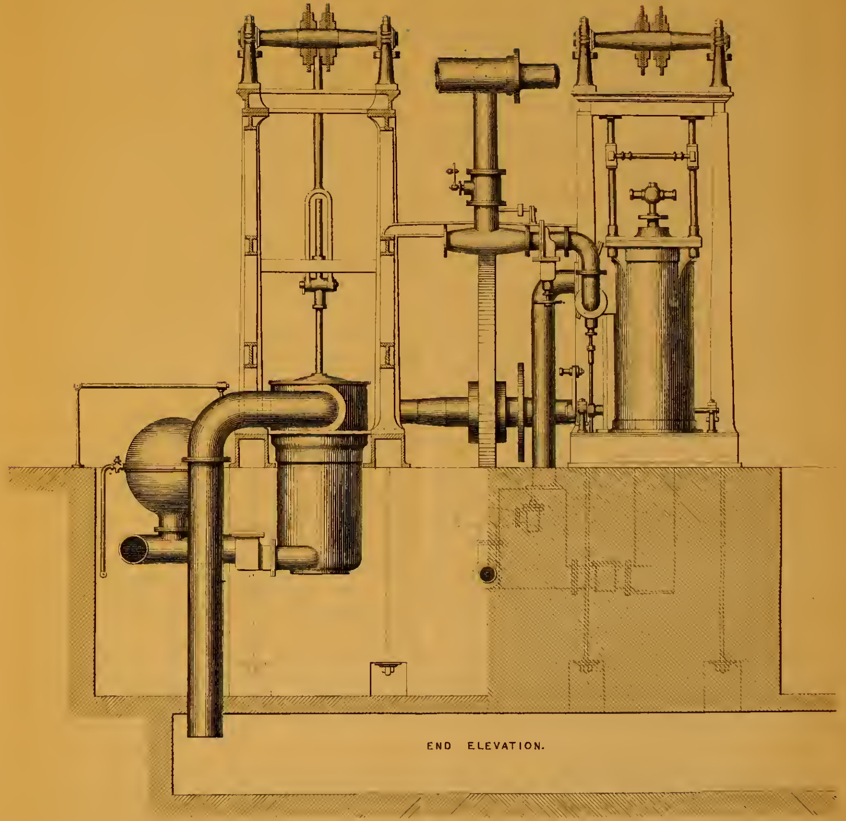
Inches 6 0 1 2 3 4 5 10 15 20 25 Feet.

ABA EL WAKF SUGAR MILL.

VAGUUM ENGINES.



SIDE ELEVATION.



END ELEVATION.

Scale ¼ Inch = 1 Foot.

Ins 12 6 0 1 2 3 4 5 10 15 20 Feet

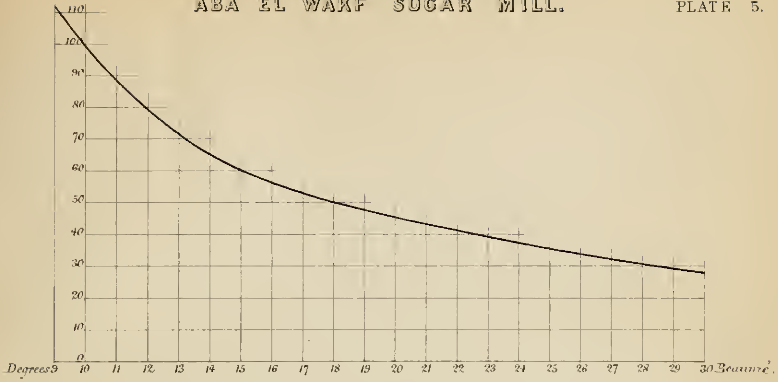
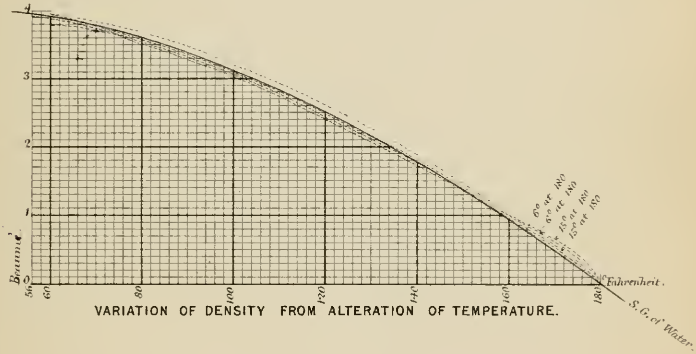
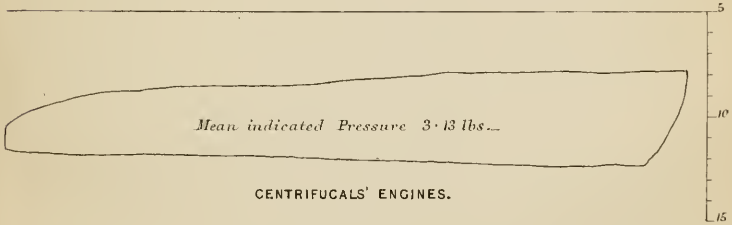


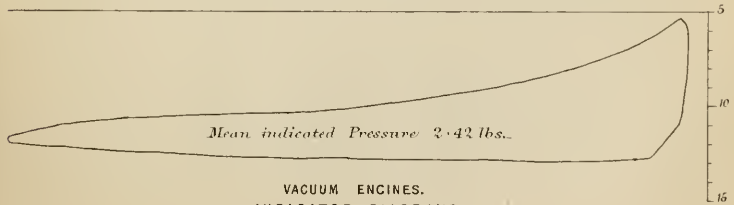
DIAGRAM SHEWING REDUCTION OF VOLUME IN CONCENTRATING CANE JUICE.



VARIATION OF DENSITY FROM ALTERATION OF TEMPERATURE.



CENTRIFUCALS' ENGINES.



VACUUM ENCINES.

INDICATOR DIAGRAMS.

Mr. Anderson said, a report had been spread abroad that the results obtained were due to the use of sulphuric acid, which, it was well known, had the effect of converting crystallizable sugar into uncrystallizable. In an early stage of the investigation of the new process, experiments had been made to ascertain if sulphurous acid affected cane-juice like sulphuric acid. Canes were obtained from Egypt, and the juice expressed in England. A certain quantity was clarified by the ordinary lime process, and an equal quantity by the sulphurous acid gas method. Both were submitted to analysis, and the result was that the latter gave a slightly higher result in crystallizable sugar than the former.

Mr. Redman observed that sugar was likely to become a large staple produce of the Australian colonies. The type of sugar-machinery hitherto used in the West Indies had been but slightly varied from, and he believed that described in 'Ree's Encyclopædia' nearly applied to the mills of the present day. The cane was crushed by horizontal or vertical rollers. About thirty-seven years ago he was resident in Barbadoes, where one class of machine was universally used, driven principally by wind-mills. The subsequent manipulation was very simple, compared with the elaborate processes described in the Paper; but he thought the manufacture, from that day to the present time, had hardly been improved. There had been a number of patents taken out for improvements in this class of machinery, of which the Messrs. Blyth of Limehouse, he believed, were the largest manufacturers, especially for the West Indies and the Isle of France; and the crushing-mills all possessed three cylinders, either horizontal or vertical. The horizontal cylinders were preferred at the time he spoke of. The principal difficulty hitherto had been in regulating the space between the cylinders for crushing the cane, and feeding them properly. Several patents had been taken out with that object in view, using adjustable gear, to vary the distance between the axles. These engines were frequently strained by overloading them with cane, by which the framework was liable to be broken; but various improvements had been effected in the supporting frames. He believed one person had enrolled a patent for converting the cane into what he termed sawdust, by sawing it with circular saws and then passing it through the cylinders.

In the West Indies, the period of raising the crop of sugar-cane varied from twelve months to fifteen months, the canes being planted during the rainy season; but some cultivators advocated cropping at an earlier period. The question of raising the crop on sugar-estates in South Australia was one of great importance, and those who engaged in this occupation found to their cost, in the districts of Queensland and Brisbane, the canes were fatally affected by intermittent frost. In Egypt, he believed the cane was raised and harvested within a period of nine months. The question was, whether by irrigation or planting sufficiently early, there was a possibility of raising the crop in Australia before the period of frost commenced. He knew several estates that had been laid out for sugar cultivation which were now being discontinued as sugar estates, and were being converted into grazing tracts.

Mr. Anderson said the simplest way of regulating cane-mills was to make the engines powerful enough to perform about three times the average work brought upon them, and they would then surmount any obstacle. He had seen canes go over the top roller, when the mills were fed too fast, without any harm being done; but for such treatment the machinery must be sufficiently strong.

Mr. J. Shears noticed that the Author had not stated the percentage of juice obtained. The machinery at Aba was ingenious, but the rollers were unnecessarily large. The prime necessity in a sugar-cane mill was an apparatus sufficiently rigid to extract the whole of the juice available for sugar. Nearly all sugar-mills were now driven at a uniform rate at the periphery; and whether the rollers were 4 ft. in diameter or 30 in. in diameter, if rigid, no more juice would be extracted by them in one case than in the other. He assumed that a mill with rollers of 30 in. or 32 in. diameter was sufficiently rigid to extract all the juice that could be obtained. The sugar cane contained about 80 per cent. of juice which was of service to the sugar manufacturer; a further extraction of the waxy part of the cane interfered with the clarification, and impaired the subsequent operations. Therefore, if a mill of a certain length could produce with a smaller diameter of roller as much juice as one of larger diameter—and if, as was the case, less power would be required to drive it—much of the first cost of the machinery might be saved, and there would be greater economy in making the sugar. On the whole, he thought the Author had made the rollers of an extreme size.

When one of the vacuum pans in use at Aba—in which he was interested as a manufacturer—was tested on the 25th of January, 1871, he believed that Mr. Anderson rather expected to see it collapse under pressure. The exterior surface was about 200 superficial feet, upon which there was a crushing power of about 167 tons; the copper was only about $\frac{1}{4}$ in. thick. It was not surprising that those who were unacquainted with the tough nature of the material should think the vacuum pan would collapse under such a pressure. The pans were proved under a vacuum, obtained by first putting a small quantity of liquor into them, and then heating them with steam; a vessel containing about 300 gallons of cold water was next hung up over them, and when the pans were well heated, and the steam sufficiently blowing through, every valve and cock was closed except one, by which the 300 gallons of water trickled into them, and a vacuum was produced. In one case, when the cock was closed, a vacuum was attained equal to $26\frac{1}{2}$ inches of mercury, which was maintained for several hours. The vacuum was observed during three successive days. Twenty-four hours afterwards, the vacuum shown by the mercurial gauge had only gone down to 17 inches, and on the following day to 14 inches, the decrease being at the rate of only 0·125 of an inch per hour. It then became necessary to break the vacuum, to take the pan to pieces for shipment; and he calculated, if the vacuum had been allowed to expend itself, nearly eight days would have elapsed before the atmospheric pressure would have been attained.

Mr. G. Phillips, through the Secretary, said that he considered the modes of producing and refining sugar detailed in the Paper to be radically wrong. Sulphurous acid gas as a bleaching agent of caramel in a sugar solution was detrimental, while, on the other hand, pure animal charcoal was capable of defecating and decolourising the lowest description of sugars, molasses, and treacle, in a few minutes.

The greatest difficulty had been experienced in introducing the various improvements which had already been adopted. He would instance the vacuum-pan. Howard, the inventor of this valuable aid to sugar-refining, nearly ruined himself, and some of his friends also, in his endeavours to perfect the apparatus, and, when perfected, had the greatest difficulty in effecting its introduction; the sugar-refining trade systematically opposing it. For some years, five London houses held their own on the old plan, by stating that their 'refined sugar' was not 'steam sugar;' and, as some portion of the public refused to use the so-called steam sugar, the houses in question flourished for a limited period; but when the public became enlightened the vacuum pan came into general use.

The centrifugal machine might also be cited. The elder Mr. Finzel—father of the present Mr. Finzel, the large sugar refiner at Bristol—invented the centrifugal machine for drying sugar crystals. Here, again, as in Howard's case, the sugar refiners refused to adopt so valuable an invention, and during the term of the patent only two licences were granted. Mr. Finzel, however, being a sugar refiner, worked his own invention, and realised a large fortune by it.

The introduction of non-porous moulds afforded another illustration. Formerly porous moulds were used for crystallizing; the loss of sugar, in consequence, was something considerable. The non-porous moulds were rigorously opposed, on the plea that porous moulds favoured crystallization; but this invention having truth on its side, like Howard's vacuum pan and Finzel's centrifugal machine, ultimately made its way.

Other instances might be named; but the preceding were sufficient to show the dead weight that had to be moved, in the shape of ignorance, prejudice, and vested interests, in introducing an invention, however valuable it might be, to a stereotyped trade.

It was stated that 400,000 tons of sugar were refined in this country annually, and that the cost to the refiner for every ton of sugar refined was not less than 20*s.* per ton for the charcoal employed in the refining. Any process, therefore, which would effect a saving in the process of refining would relieve the public of a very heavy tax on the refined sugar consumed.

The defecating and decolourising power of pure animal charcoal was due to galvanic action; the charcoal was the positive electrode, or pole; the sugar and albumen neutral mediums, or inert agents of communication; and the colour and caramel the negative electrodes. It followed from this that the electrolytes were colour and caramel, and that these would be found attached to the charcoal, the inert medium, sugar and albumen, passing through the charcoal bed together. Again, as pure animal charcoal failed to separate albumen from a sugar solution, heat must be employed to coagulate the albumen, and then filtration to separate it from pure sugar solution.

In the production and refining of sugar, a temperature of 180° should never be exceeded. In treating cane-juice in the cold with pure animal charcoal, the sugar manufacturer should defecate and decolourise the solution in five minutes. The density of cane-juice was admirably adapted to this treatment; and the after process to free the purified juice of albumen should be as rapidly performed as possible. The juice would then be safe, as pure sugar in water would not ferment, or undergo any change, except that of crystallization. He had a specimen of a weak solution that had been kept for seven years, and no change had taken place in it except the formation of a few minute crystals.

The mere burning of bones would not produce pure animal charcoal, however experienced the burner might be; for there was always animal matter left in them—sometimes of an offensive character—and always colour, which frequently injured the refiner's work. He could not too much impress upon those who produced and refined sugar the importance of having pure animal charcoal as a means of defecating and decolouring sugar solutions—and even molasses and treacle—in a few minutes.

Mr. C. W. Siemens said the Paper dealt with two separate subjects, one of a mechanical, and the other of a chemical character. It appeared to him that the Author had very satisfactorily solved the mechanical questions involved. The arrangements of the mill-gearing had evidently proved successful, but it was a question open to discussion whether so large a diameter of roller was beneficial in a chemical and economical point of view. By using large rollers a greater amount of saccharine matter could, however, undoubtedly be extracted. The system of raising the juice from one receiver to another by a centrifugal pump, instead of by the old 'blowing-up' arrangement, was also an improvement; because in admitting steam in contact with the saccharine solution, condensation would take place, and the work of evaporation would be increased; and if the centrifugal system was properly arranged, there need be no apprehension that it would churn the saccharine solution. Considerable ingenuity had been displayed in the construction of the evaporating apparatus employed. The steam boiler had been placed immediately below the concentrator, or, as it was called, the 'juice boiler,' and thus the steam generated in the lower compartment at once condensed against the upper surface of the steam boiler, which was also the bottom surface of the juice chamber—the surface contact being increased by means of tubes—and in that way losses of heat by radiation or otherwise were avoided, and the same water was re-evaporated again and again. It was interesting to observe that the surface in contact with the fire could be made three or four times smaller than the surface necessary to convey the heat from the steam to the saccharine solution.

The use of the steam raised from the saccharine solution was another novelty. It was made serviceable not only for working the vacuum pan, but also for driving the engine. There could be no reasonable doubt about the mechanical efficiency of applying the steam raised from the juice to driving the engine, and theory in this case had been justified by the result; but a question of a chemical nature arose, namely, whether the juice itself was not injured by raising from it steam of sufficient pressure for such purposes. It was well known that when juice was concentrated by the direct application of fire, a considerable portion of the sugar was converted into molasses, or uncrystallizable sugar, and it would be desirable that the opinion of persons practically engaged in sugar boiling operations should be ascertained as to whether the direct application of heat had not been carried too far, or whether the same amount of juice would not have yielded a larger amount of crystallizable sugar, if the direct application of heat in the vacuum pans had been resorted to exclusively.

It might be urged that such an amount of heat could not have been obtained, owing to the larger consumption of fuel which would have been requisite; but there was a process now in course of trial, partly suggested by himself, to evaporate entirely by vacuum pans, and at the same time to economise heat by forcing the steam generated at low pressure within the vacuum pan mechanically into the tubes surrounded by the juice.

The main feature of the Paper was the substitution of sulphurous acid for charcoal in removing the colouring matter. If sulphurous acid could be applied without practical drawbacks, great saving must undoubtedly arise, because animal charcoal was an expensive substance, and involved the employment of complicated apparatus to revivify it for repeated use. But the question arose—whether in using the sulphurous acid method a portion of the crystallizable sugar was not converted into uncrystallizable, or grape sugar? It was a well-known fact that if sulphuric acid was put into a solution of cane sugar, its mere contagious action, so to speak, would convert an indefinite amount of the solution into uncrystallizable, or grape sugar, which, though very similar as to chemical constitution, was of a much less sweetening character. It was doubtful whether the sulphurous acid was always free from sulphuric acid, particularly if, as was suggested, oxydising agents, such as peroxide of manganese, were also employed. An increase of grape sugar would not necessarily imply a diminished yield, because when the solution came to a certain consistency it might solidify. He would inquire whether in the sugar prepared at the Aba mills there was not a proportion of uncrystallizable, or grape sugar precipitated with the crystallizable, or cane sugar? He did not believe in the theory put forward that galvanic action would be set up between the charcoal and the colouring matter. The conditions of sugar solution were totally at variance with what might be expected in a galvanic battery, where two conductors of different affinity for oxygen were brought into metallic contact while immersed in acidulated water.

In regard to the experiments which he had referred to as having been conducted for effecting the concentration under a vacuum so as to attain the advantage of using the steam repeatedly, he might add that many years ago he proposed to evaporate liquid cane juice by pumping the steam from the vacuum pan, which was in the form of a locomotive boiler, into tubes surrounded by liquid in order that it might be condensed there. To sustain the further evaporation of the same liquid, a steam engine and pumping cylinder were employed, whereby the steam generated within the evaporating pan at about half the pressure of the atmosphere was compressed, and forced into the tubes at double, or atmosphere pressure. Its condensing point was raised in compression from 180° to 212°, which difference sufficed to cause the recondensation of the steam within the tubes and a continued ebullition of the juice, the same latent heat being made to serve over and over again. The only real expenditure in this operation was mechanical force, but the steam employed in generating this force was necessarily much less in amount than the steam compressed by it through half an atmosphere. Moreover, the exhaust steam of the engine was made available to make up for the loss by radiation, and for bringing the cold juice up to the boiling point.

Such a process could not fail to work practically, but the mechanism involved in it was of a nature to make its application costly. The project was revived last year by Mr. Robertson, who after hearing the Paper on "Pneumatic Despatch Tubes; the Circuit System," by Mr. Carl Siemens, M. Inst. C.E.,[1] conceived that the steam blast apparatus referred to, being capable of maintaining a vacuum of 20 inches of mercury, could be made to serve also to force the vapour raised in a vacuum pan into the evaporating tubes of the same or another pan, and thus to combine the advantage of evaporating the juice under a reduced pressure with that of repeatedly using the latent heat of the steam. Mr. C. W. Siemens considered this plan to be superior to that originally proposed by himself, inasmuch as the apparatus employed was simple and inexpensive. When tried in London, Mr. Robertson found that a vacuum of 20 inches could be maintained in his vacuum pan. In that case, as in the former, the steam employed in compressing the vapour in order to fit it for

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[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xxxiii., p. 1.

recondensation was added to the compressed steam and served to make up for losses by radiation, &c. It was evident that by such an arrangement the latent heat of the same steam could be used, not once or twice, but several times, the heat passing again and again through the same metallic surfaces. Whether such a plan could be worked advantageously in practice in the East and West India sugar factories was a question upon which Mr. C. W. Siemens had no experience to adduce, but the experiments had at any rate proved the correctness of the principle involved.

Mr. E. Beanes said he also thought that the diameter of the rollers for the mill were unnecessarily large. If the length of the rollers had been extended to 8 ft., three mills might have been made to do the work which four mills did now. He had seen rollers, 8 ft. long, work very well in the West Indies.

He had found no difficulty in the use of pinion or crown wheels when the rollers were set at a proper distance. An inch between the front roller and the top one was an unusually wide space. He had never seen more than $\frac{3}{8}$ths of an inch allowed. By the arrangement adopted by the Author, the whole of the work was thrown on the top and back rollers; consequently the gain in other respects in large diameter would be lost by the work coming on two rollers instead of three. He was under the impression that the large diameter had been adopted for the sake of feeding the mills better; but he had seen rollers of 28 in. diameter, with which there was not the slightest difficulty in feeding the mill. That might have been from the way in which they were turned, the last cut having been in the form of a fine thread graven with a pointed tool. He had seen those rollers fed by tipping cart-loads of canes from the railway directly on to the carrier.

There could not be much reliance placed upon statements of the percentage of juice obtained, because it depended upon the quality of the cane. He had seen 70 per cent. or 72 per cent. of juice from Otaheite cane, while with the same mill not more than 50 per cent. was obtained from ribbon cane.

So far as he had seen, no pump was so good as the 'montejus.' He did not observe any arrangement had been described for washing out the pipes and pump. That might not be so necessary in Egypt, because rich juice contained less nitrogenous matter than poor juice.

With respect to clarification by means of sulphurous acid, he would like to hear from the Author the part of the process which he considered to be new. If it was in passing sulphurous acid into cane-juice, and afterwards adding lime, that was the process of

Mr. Stewart of Louisiana, who had stated that he had established it in more than a thousand instances. If the Author first added the lime and afterwards the sulphurous acid, then it was a process copied from Mr. Beanes. It had been carried out on thirty-two plantations in Cuba, and also in Java, and it was about to be introduced into Queensland.

The bleaching power of sulphurous acid, as applied to cane-juice, was, he believed, one of its least valuable properties. If its colourless salts could be washed out, as was done when used for bleaching wool, it would be of some value even for removing a little colour; but this could not be done with cane-juice; and if the acid was neutralized, or evaporated from the juice, the colour would return. Its great value lay in what he had before stated, namely, its property of rendering insoluble the nitrogenous substance, gluten, not albumen or casein, as had been stated. The former was rendered insoluble by simply boiling the juice, the latter would be precipitated, when lime was added to it, by the formation of the earthy salt, calcium acetate. But such was not the case with gluten; it was not precipitated by either of those means.

There were some facts not generally known with respect to the decolourising power of animal charcoal. It was in proportion to the carbon—or call it carburetted hydrogen—surface exposed; and its power of absorbing lime was in the same proportion. He thought, if this were generally understood, such samples of animal charcoal as those on the table, being the kind used in Egypt, would not be exhibited. He had seen similar samples in some beet-root factories in the north of France; flints might almost as well be used as charcoal of such a size. Sulphurous acid, he had no doubt, would compare favourably with such charcoal as that.

Many—even chemists—were under the impression that the internal portion of the charcoal comes into action in decolourising; but such was not the case, as could be shown in many ways. For instance, as in testing it by lime-water—after it had entirely lost the power of removing lime from lime-water—if broken up into smaller pieces, thereby exposing new carbon surfaces, its power of absorbing lime would again return; but if all its pores had been filled before breaking it into smaller pieces, that result would not have happened.

The Author mentioned that the juice took up thirty volumes of sulphurous acid gas. If the gas was passed into hot juice, it would be impossible it could take up so large an amount. If it was passed into juice at a temperature of 75°, that quantity might possibly be absorbed; but it would take at least 24 hours to do it. He however believed that no such quantity could be used or was necessary with the good quality of juice the Author worked with. A description should also have been given in the Paper of the chemical action which the sulphurous acid had upon the cane-juice.

Cane-juice contained gluten in more or less quantity, according to the soil on which it was grown. Rich soils gave it in considerable abundance, poorer soils gave but little. From the stunted size of the canes, which were only about one inch in diameter, he should infer that the canes which the Author had to deal with were grown on very poor soil. If juice at 10° Beaumé, being 1,070 specific gravity, took up thirty volumes of sulphurous acid, it would increase the density 13°, making it equal to 1,083 specific gravity; and therefore he thought it unlikely that quantity was used. Gluten ordinarily gave sugar-masters much trouble. This substance was soluble in the juice of the cane, as also in alkaline solutions; consequently, if the sugar-master put in too little lime the gluten remained in solution, and if too much, the same result occurred. Gluten was insoluble in sulphurous acid and the sulphites, and, by rendering it insoluble, it could be easily removed with the scum; but a much less quantity was required than was generally used. Malt contained very much more gluten than cane-juice, and it was found that 1 per cent.—of the weight of the malt—of acid sulphite of sodium was sufficient to render insoluble all the gluten of the malt.

He was of opinion that precipitators might do very well for the cane-juice; but when it became sirup at 22° Beaumé, the minute insoluble substances held in suspension took a long time to subside. Instead of the short time mentioned in the Paper, it would probably require twenty-two hours to clear thoroughly at 22° Beaumé. It was a mistake to finish the clarification at 22° Beaumé, because at that density the sirup contained matters which became insoluble as the density increased up to 30° Beaumé; therefore, if the clarification was carried on up to 30° Beaumé, and the sugar passed through bag-filters, the whole of the insoluble matters would remain behind, and the sugar would be of better quality.

A long experience had convinced him that sulphurous acid could not compete with animal charcoal where white sugar was required. To obtain a perfectly white sugar, an equally white sirup must be used, because a portion of sirup was shut up in the plates of each crystal, and could not be washed out. If merely grocery sugar was required, there was no objection to sulphurous acid; but it was unsuitable when white sugar was wanted. The whitest sugar made with sulphurous acid was grey, compared with real white sugar; and it would be unsaleable in the London market. Sugar-refiners would not pay the price for it, and ordinary consumers would prefer the yellow sugar.

The apparatus for boiling juice under pressure described by the Author was not new; it was eighteen years old, to Mr. Beanes' knowledge; but he never approved of it, and believed that very serious injury might be done by it. To boil sugar under a pressure of 6 lbs. would be equal to a temperature of 231°. If a solution of perfectly white refined sugar was placed on a bath of common salt (chloride of sodium) and left there for three hours, it became quite yellow; now the boiling temperature of common salt was 224°, which was considerably under the temperature used here.

He thought the vacuum-pan was not the best kind of evaporator; at any rate, where it was used a larger heating surface than that described in the Paper would be necessary, especially with steam at such a low temperature. The use of megass alone as fuel was not a new idea, as it had been carried out for at least twelve years. He could give the names of several plantations in Cuba where megass was used, to the total exclusion of wood and coal.

Mr. James B. Alliott said, in the machinery under consideration the rollers were remarkable for their large diameter. In the operation of crushing the sugar-cane, there were two matters to be attended to: one was to have sufficient pressure to extract the juice, and the other was to take care that the already crushed cane did not in its passage out of the mill soak up the juice already extracted. So far as the latter point was concerned, no doubt large rollers were an advantage, because the distance between the place where the juice was expressed and that where the cane was expelled was greater than in small rollers; but so far as the power needed to produce a certain intensity of pressure was concerned, that would be much greater with large than with small rollers. The usual system was to make the rollers of such a diameter only as was necessary to give the requisite rigidity, and that might be obtained, with rollers of the length mentioned, namely, 5 ft. 6 in., by giving them a diameter of only 28 in. or 30 in. instead of 40 in., as in the Aba mills. There was, however, a greater surface of cane under pressure at the same time in the Aba mills than in the cases of smaller rollers. Therefore, if the pressure per inch of cane were the same at Aba as in mills with smaller rollers, much more engine power would be needed; or, if the engine power were the same, much less pressure per inch of cane would be exerted by the Aba mills than by those having rollers of the usual diameter. As had already been remarked, the knowledge of the percentage of juice extracted was not very material, because it varied so much according to the quality of the cane; but it was of great interest to know what percentage of juice was left in the megass. On estates in which he was interested in the West Indies, he observed, this year, that the percentage of juice left in the megass had been about 47 per cent. of the total weight of the fresh megass. An average sample of megass, weighing 10 ozs., when washed in water and carefully dried, weighed 5·27 ozs., or rather more than half the original megass. From the quality of the megass as described—namely, that its loss in weight was over 40 per cent. before it was used for fuel—he should not infer that the megass was more perfectly crushed in Egypt than in the West Indies; and therefore it might reasonably be presumed that as perfect crushing was obtained with rollers of comparatively small diameter as with the very large rollers employed in Egypt.

Another matter which needed discussion was that of the evaporation of the juice under pressure. For years past the object of most of the inventions which had been made for the manufacture of sugar had been to reduce the temperature at which sugar solutions had been evaporated. Any temperature over 140° was prejudicial to solutions of sugar, and the damage done varied directly as the time of exposure to heat and as the square of the difference between 140° and the temperature attained. The evaporation in the trays at Aba was conducted under a pressure of from 3 lbs. to 6 lbs., which corresponded to an increase of the temperature above the normal boiling point of the liquor in the open air of from 8° to 16°.

Thus, taking 213° as the normal boiling point of juice, gauging 10° Beaumé, the injury done by boiling it in the open air for, say 10 minutes, would be represented by 53·29, while it would suffer, by being boiled for the same length of time under a pressure of 3 lbs., an injury represented by 65·61, and this would be increased to 79·21, were the pressure on the juice raised to 6 lbs.

When comparing the trays in use at the Aba factory with the ordinary Jamaica train or 'Triple-Effet' apparatus, this greater intensity of damage was to a considerable extent neutralised by the short time during which the juice was exposed to pressure, since it only remained in the concentrating trays about eighteen minutes, while in the ordinary train of open pans it would be exposed to the pressure of the atmosphere sometimes for an hour and a half, or even longer; and in the 'Triple-Effet' apparatus, though boiling at a lower temperature than in the open air, it would be exposed for two hours, or three hours, to such a temperature as the pans attained. It might be that the juice did not suffer so much in the evaporating-tray as in the ordinary open train; but he did not think, on that account, that it was the proper course to evaporate under pressure.

With respect to the readiest methods of concentration, if the Aba tray were an improvement upon the ordinary system, certainly the 'concretor,' though condemned in the Paper as one of the rudest machines used in sugar manufacture,[1] presented advantages over the Aba trays. In the Aba trays the juice had a temperature of from 8° to 16° above its normal boiling point, and was exposed to this temperature for eighteen minutes, and this gave a concentration from 10° Beaumé up to 21° Beaumé. In the concretor the juice was concentrated from 10° Beaumé—not merely up to 21° Beaumé, but up to 28° Beaumé or 30° Beaumé—in less than ten minutes, and at a temperature from 8° to 16° less than that it was exposed to at Aba; this was if the concretor was being used, as it generally was, for making concrete sugar. If it was employed as a means of concentrating for the vacuum pan, the juice would be raised from 10° Beaumé up to about 20° Beaumé in seven minutes or eight minutes, and exposed to a temperature never exceeding 214°; while it would be raised from 20° Beaumé, to 28° Beaumé, or 30° Beaumé, by exposure for about fifteen minutes in another portion of the apparatus where it would only be subject to a temperature of about 170°, a degree of heat not much higher than it would be exposed to in the vacuum pan itself.

If, as was generally supposed, the application of heat was prejudicial to sugar—and if the damage caused was in exact proportion to the time during which the sirup was exposed to heat—he thought it would be found that the Aba trays were not an improvement upon apparatuses already in existence for many years past.

With regard to the defecation of the sugar, there could be little doubt that sulphurous acid gas possessed very powerful bleaching properties, and that it would remove a very large portion of the colour present in the juice; but if the whole of the sulphurous acid was not removed, some change went on in sugar which had been exposed to it. Whether it was because the sulphurous acid was gradually oxidised and became sulphuric acid, and thus caused the evil, he left it to others to say; but many instances of such changes had been related to him by those who had observed them.

Mr. J. G. C. C. Godsman expressed a hope that, in an alimentary

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[1] *Vide* ante, p. 39.

and sanitary point of view, and considering the large consumption of sugar by the lower and working classes, the question would be fully sifted whether the use of sulphurous acid in the preparation of sugar was prejudicial to health as compared with the other process of animal charcoal. In the poorer neighbourhoods, his attention had been called to the inferior character of the sugars ordinarily sold, and in some cases to the circumstance that the acid with which they appeared to be impregnated had sensibly affected the paper in which the sugar was wrapped.

Mr. W. Knaggs said he had patented the evaporating tray, referred to in the Paper, in 1865-66, and likewise the entire system of clarification described; and he went to Egypt and worked it. The large diameter of the rollers had been several times referred to, and some speakers expressed their opinion that they did not crush the cane so well as smaller rollers would have done. All he could say was, they did not crush the cane properly, because, being very short, a great depth of cane was required to feed them continuously. It was necessary to set the rollers an inch apart, consequently, with a glut of cane the mill stopped; and if the mill was slacked the cane came away unground. Had the rollers been longer and of less diameter, so as to admit of a wider feed, they would have done better. No experiments were tried at Aba to determine the capabilities of the rollers. He was there when the mill started, and he, his son and his nephew were the parties in charge of the mill. With regard to the sulphurous acid process, the Author had left out an important item in reference to the clarification. Not a particle of the sugar was made without the use of permanganate of soda, and part of Mr. Knaggs' patent was for the use of sulphurous acid combined with permanganate of soda. The action of sulphurous acid was to coagulate the albuminous principles in cane-juice and to bleach the green colouring matter and throw it up in a state of scum. An experience of thirty years as a planter and manufacturer of sugar had convinced him that this was the best means of clarifying the cane-juice. With the use of sulphurous acid and lime only, the juice generally remained cloudy; but the application of a small quantity of permanganate of soda left the liquor perfectly bright and clear. He considered the centrifugal pump was far preferable to the 'montejus' or the ordinary juice pump for raising the cane-juice. The juice pump was never in the same capacity as the flow of juice from the mill, and air was consequently injected into the juice, promoting decomposition and fermentation; while the 'montejus' was always more or less in a state of acidity and dirt.

The clarifiers, he considered, should have been square to facilitate the operation of scumming, as it was necessary in this process to remove the scum as fast as it rose on the top of the clarifier, before the lime was put in to neutralize the acids for purposes of boiling. The clarifiers acted well for the evaporating trays, the only innovation upon his original arrangement being that nozzles projecting upwards had been substituted for transverse tubes. But there was one great fault in connection with the alteration: the steam pipes in connection with the safety valves rose through the scum and froth of the boiling cane-juice, and as they were heated to a high temperature by a pressure of 60 lbs. of steam internally, the sugar became charred on their surfaces, and formed a black coating, which darkened the juice. He had protested against this arrangement.

Without wishing to detract from the merits of the concretor as a great improvement on the old copper wall, he considered that heating a thin film of the juice in the open air did more harm to it than heating it in close vessels not exposed to the air. The system of boiling the juice under pressure was contrary to his wishes, and that was the only originality the Author of the Paper could claim. The Author proposed to work the vacuum pans by putting a back pressure on the trays, a process against which Mr. Knaggs had also protested, and proposed instead that the Author should make the vacuum pans with increased heating surface beneath, so that the steam might escape freely from the trays.

He would offer no other remarks except to put forward his claim as being the inventor of these different processes, and to state that he worked the entire process at Aba from beginning to end.

Mr. Anderson said, that although, in the first instance, Mr. Knaggs had brought this system of making sugar under his notice, he found afterwards that what Mr. Knaggs claimed to have invented had been invented before. The sulphurous acid process had been patented in 1838 and several times since. Permanganate of potash, the use of which Mr. Knaggs claimed as a novelty, was not used in the experiments made by Mr. Ogston in Egypt, and, under the best chemical advice, had been completely abandoned. The tray was Mr. Knaggs' invention, improved by the introduction of the nozzles.

Mr. G. H. Ogston stated his belief that no permanganate of soda was used during his experiment at Aba. He always disapproved of it, and understood that Mr. Knaggs had, in deference to that opinion, given instructions to discontinue the use entirely whilst the experiment was in progress.

He would shortly state his reasons for objecting to permanganate of soda being introduced into solutions of sugar, especially in the presence of sulphurous acid, and chemists would readily recognise their importance. Sulphurous acid was converted into sulphuric acid by oxydation, the latter acid being highly destructive of cane sugar when boiled with it; and as permanganate of soda was an oxydating substance of great power, it seemed, in the last degree, dangerous to bring these bodies together in boiling cane juice. He had never seen permanganate of soda used during the experiment, and had every reason to believe it was not used.

Mr. W. Knaggs said he had a letter from Messrs. Easton and Anderson, in which it was stated, that Mr. Ogston had made experiments in clarifications, and decided that the permanganate of soda process was beneficial and could do no harm whatever.

Mr. W. E. Rich remarked, with respect to the large size of the cane mill rollers, that their diameter was determined by the Khedive himself when the factory was first talked of. It could be easily demonstrated that large rolls required exactly the same power to crush a given thickness of cane at a given surface speed as small ones—excepting only a slight excess for overcoming the increased journal friction in consequence of the greater weight; and that excess might be estimated 'pro ratâ' when other things were the same. He could say with confidence, that no more power was used in crushing a given amount of cane between rollers of large diameter than in those of small diameter; and in sugar factories of sufficient extent to require one or more powerful cane mills, large rolls were decidedly preferable to small ones.

Time was an important element in the efficient crushing of fibres, and the time during which a particle of cane was under compression in a mill varied directly as the diameter of the rolls. In a mill with rolls of 4 ft. diameter, with a surface speed of 18 ft. per minute, the cane was subject to pressure during twice the time it would be in a mill with rolls of 2 ft. diameter going at the same speed. A rate of 18 ft. per minute was the established speed for cane mills in the West Indies, and the Aba mills were designed to run at that speed, but, in point of fact, they were run at 27 ft. per minute and 30 ft. per minute, sometimes even at 36 ft. per minute, with equally good results in the extraction of juice. Large mills could be made more rigid and stronger than small ones, and as they presented wider jaws for the reception of cane, a thicker layer could be carried through, and therefore much more work could be done. At Aba, the stream of cane into a mill was generally from 15 in. thick to 18 in. thick, and sometimes it ran over the top rolls. The engines which worked these mills were capable of developing power three times as great as the average power necessary for driving them. This amount of power was required to overcome the jams occasioned by excessive gluts of cane, and the way in which such jams were overcome proved the strength of the mills. When a mill became choked and stopped, the practice was to reverse the engine, and then start it again at full speed, and the jam was overcome without the slightest injury to any part of the mill; up to the present time not a single casualty to the gearing had occurred.

The system of gearing presented great advantages over the ordinary system. At first, it might be considered complicated; but a closer examination would show there was no ground for that apprehension. Every pair of wheels was always in true gear with two or three teeth in contact, the load per inch of the width of face was in no case excessive, and, what was more, although there were ten wheels instead of seven, as on the old system, the ten were of smaller and more convenient sizes for manufacture and transit, and in the aggregate weighed 2 tons less than if the mill was made on the old system. Some remarks were made as to the strength of the copper vacuum pans. They were 10 ft. diameter and $\frac{1}{4}$ in. thick, and were built as nearly as practicable in the spherical shape. He did not know of any means of ascertaining the collapsing pressure on thin spheres of copper, except by direct experiment; but it was fair to estimate that a sphere 10 ft. diameter and $\frac{1}{4}$ in. thick was at least twice as strong as a thin iron cylinder 10 ft. diameter, 10 ft. long, and $\frac{1}{4}$ in. thick. If that were so, the collapsing pressure on these pans was at least 84 lbs. per square inch, or six times the maximum working pressure.

Mr. John C. Wilson said he also had a claim in regard to a portion of the sugar mill described in the Paper. He patented the wedge motion for elevating the lower rolls on the 2nd of December, 1861. The arrangement in this case was the same, except that his wedge was inclined in the other direction, the large end outwards, and the small end nearest the centre of the mill. The latter arrangement had an advantage in this respect, that the strain from the pressure was not thrown outwards as in the case of the Aba mill, but was thrown inwards upon the side frame of the mill, and added materially to the strength of it.

With regard to the machinery, the condensing engine was not now considered to be the best engine for driving sugar mills, but it was admitted that either the horizontal or vertical high pressure engine was the best, and these were generally used by the largest manufacturers of sugar mill machinery. The high pressure engine was economical in this respect, that the exhaust steam was used for heating the clarifiers, and it was in itself simple and economical, and did not require so much attention as a condensing engine. He thought there was an objection in having so much gearing close to the mill. It was much more convenient to have the gearing at a little distance, as it allowed the mill to be more easily cleaned, and had other advantages. He thought there could be no serious objection to the employment of the usual three pinions for driving the rollers; they had been in use for many years, and no practical objection had been found in their working. The roller most out of gear was the feed roller, and that had little work to do, being admittedly, in this mill, 1 in. away from the top roller. The megass roller did most of the work and was most in gear. He thought the ordinary rectangular clarifier, with heating pipes in the bottom, and a scum trough running all round the top, was much better than the one adopted. The heating pipes in the rectangular clarifier were immersed in the juice, and there was, therefore, no loss of heat with them, whereas, this clarifier, on the French system, entailed a serious loss of heat by radiation from the bottom casing.

He was surprised that no mention had yet been made of the fact that the open fire process was absolutely beneficial in the ultimate crystallization of the sugar when not extended beyond a certain point. It made a firmer grain with less molasses. The ordinary system of open fire evaporation in iron pans firing with megass, and the waste flame passing through a multitubular boiler placed in the flue of the copper, which raised all the steam necessary for working the whole plant of the factory, was found practically to be a very economical arrangement. Although he had pointed out what he considered would be improvements in the design of the work, he had no wish to detract unduly from the merits of the Paper. On the contrary, he thought the Author deserved great credit for the boldness and originality of his design, which appeared to have been well worked out.

Sir John Alleyne, Bart., remarked that the rollers of a sugar mill had to be set in the best way for expressing the juice from the cane as a continuous operation, and they required no other adjustment after being set to the proper gauge. It was very different from the case of a mill rolling iron plates of different thicknesses. He thought, looking at the machinery as a whole, the amount of gearing in the Aba mill was more than there was occasion for. He was acquainted with the working of three sugar estates in Barbadoes. On one of these the juice was raised by centrifugal pumps, in consequence of which the weight of the sugar was less, and its price decreased. The juice should have been run straight from the mill, and then both it and the gutters would have been accessible at all times for cleaning. If air was sucked in by the pumps the juice must be at a low level, and the pumps should be stopped till more liquor was collected. But the pumping was a great evil, and he believed it was increased by the high velocity of the centrifugal pump. It had been stated that the 'montejus' condensed a large portion of the steam, but the resulting evil was not great, because the juice was practically heated, and less mischief was done in reducing the density of the juice than the pumping did by promoting acidity.

Defecation by the sulphurous acid process was a main question, as it was important to ascertain how defecation could be best carried on with least waste. Not long since, he went over many beet-root sugar factories in Holland, and there the defecation was effected by carbonic acid. There was a limekiln on the works, with a blowing engine like that for blowing air into a blast furnace, by which the carbonic acid was pumped from the limekiln through the juice. The juice was first treated with an excess of lime, and the effect of the carbonic acid was to convert the lime into carbonate of lime, which was deposited as mud. He wished to ask the chemical gentlemen present whether that was what really took place, and whether that process did not stop fermentation much more effectually and give a better defecation than the sulphurous acid process did?

Mr. Beanes, by permission of the President, asked Sir John Alleyne whether he had ever seen an instance where carbonic acid had been used with sugar cane juice? He was under the impression that sugar cane juice contained acetic acid, and as that was stronger than carbonic acid it would maintain the lime in solution.

Sir John Alleyne did not know of any instance where it had been employed with cane juice, though carbonic acid was used in all the beet-root factories in Holland he had visited; but he thought sugar could not be extracted from beet-root juice if the ordinary battery of open 'taches' of the West Indies was used.

Dr. Henry Letheby said it must have been in the minds of all present that this was not altogether a question of machinery, for it involved other principles than those pertaining to mechanics. It was evident, indeed, from the general scope of the discussion, that many important chemical principles were concerned in the economic production of sugar, and that these must be kept in view from the first moment the sugar producing plant began to sprout, until its juice was brought into the condition of crystallized sugar. In point of fact, many of the points previously touched upon were, to a great extent, subsidiary to the main question.

With respect to the growth of the cane, it was well known that if the soil was a little overcharged with saline matter, it would be found in the juice, and would seriously interfere with the production of crystallizable sugar. So, also, during the maturation of the plant, the amount of light, the presence of too much moisture, and the degree of temperature to which it was subjected, would affect the quality of the cane juice, not merely in its percentage proportion of sugar, but also in its richness in those nitrogenous matters which interfered with the production of crystallizable sugar during the processes of defecation and evaporation.

Turning, however, to one of the principal subjects of discussion, namely, the action of the rollers and crushing machinery, it was a very important question, whether it was really desirable to get all the juice possible out of the sugar cane; for it was a well-known fact that the juice first squeezed out, coming as it did from the loose cellular tissues, was much richer in sugar and less charged with albumen and saline matter than that which flowed from the harder tissues.

In the olden time, there was less difficulty in crystallizing sugar, and larger products from a given volume of juice were obtained than now, when so much greater pressure was applied, and when the yield of juice was, perhaps, almost doubled. He did not know the yield of the Egyptian canes, but formerly, in the West Indies, when not more than 50 per cent. of juice was obtained, sugar was made at a profit. Now, on an average, from 75 per cent. to 80 per cent. of juice was obtained; but that juice was so charged with nitrogenous and saline matters coming from the harder tissues of the cane, that he doubted whether it did not interfere very considerably with the profitable working of the sugar afterwards, and it was a question whether there would not be an advantage in separating the two juices from each other; for, ordinarily, they had a little less than two parts of saline matter in one thousand, and the same proportion of nitrogenous matter in the juice which flowed from the soft tissues; but, by higher pressure, sometimes nearly double that quantity of these objectionable impurities was extracted. It was evidently, therefore, an important point for consideration, whether it would not be profitable to separate the juice of the first pressure from that of the second, seeing that in the first case a much better sugar was obtained than in the second.

With regard to the action of sulphurous acid, an examination of the cane juice under a microscope directly it was expressed would show it to be full of minute granules like corpuscular germs. These were, perhaps, the immediate agents of fermentation, which, in a warm climate, took place almost immediately. As a prime consideration, therefore, those germs must be killed at once. One of the most important effects of using sulphurous acid was that it stopped their growth, for it had the effect of immediately arresting fermentation. But it did more. There was a kind of albuminous matter in cane juice, which, like common albumen, was coagulated by heat. There was also another nitrogenous substance of the nature of caseine or legumine, which, like the albumen of milk, was not easily coagulated by heat. It was, however, coagulated by sulphurous acid, and, therefore, when this acid was added to the juice, it not only destroyed the minute germs which were ready to set up fermentation, but it also coagulated the other forms of albumen, and so helped to bring these matters to the surface as a scum in the after treatment of the juice.

As regarded the use of carbonic acid, it might in some instances act beneficially—as in the case of beet-root juice—by displacing atmospheric air; but he had no experience of its use in clarifying cane juice, and he did not think it could be substituted for sulphurous acid, for it was the especial property of that acid to coagulate, and so aid in the removal of those nitrogenous matters which interfered seriously with the production of crystallizable sugar, and which tended to convert it into the degraded or interverted form, called molasses; and, so far, the sulphurous acid had an advantage over every other form of gas in attacking these objectionable albuminous products.

As to the system of evaporating sugar under pressure, which was in operation in the Aba works, every chemist who had given attention to the subject knew that when sugar, either diluted or concentrated, was subjected to a higher temperature than 165° or 170° it was changed, or, as it was termed, degraded from its crystallizable character into uncrystallizable. It was, therefore, manifestly wrong to subject cane juice, under any circumstances, to a temperature higher than was necessary for evaporation; and unless fuel was so dear that it was too expensive to get steam otherwise than by the utilization of that which came from the evaporating juice, it was a most mischievous proceeding—judged, as he judged it, from a scientific point of view—to effect the first evaporation of sugar in the manner described in the Paper. The subsequent processes of the manufacture involved chemical principles which required to be looked at in detail; but he might say the presence of albuminous matters, the presence of saline matters, the presence of minute quantities of acids, or even of alkali, from a too liberal use of it, were the chief causes of the degradation of crystallizable sugar; and although the machinery might be perfect, and the appliances for evaporation admirable, yet if these important causes of mischief were not taken into consideration, it would not be possible to realise to anything like the fullest extent the profitable manufacture of sugar.

Mr. E. A. Cowper said he did not think the advantage of large rolls was quite appreciated. He approved of the plan of driving rolls by wheels of larger diameter than themselves. The rolls for gold at the British Mint were so driven, as well as the rolls at the Sydney Mint, for which he made the drawings. Much greater steadiness was thus obtained, and the side-strain on the bearings was considerably reduced. Of course one roll must in this case be driven from one end, and the other from the other end; in each case the large wheel was driven by a pinion. There was by this means great leverage over the rollers, and much less chance of breakage. He thought large diameter was an advantage in taking in a heavy feed. In the case of the Aba mills, he understood as much as 18 in. thickness of cane was sometimes passed through. It was therefore evident the rolls must be further apart than if a feed of only 4 in. or 5 in. was put through; but the regularity of the pressure on a large mass of cane was greater than when a small thin layer was put in, as very often spaces occurred between the canes in which juice was liable to escape. He could not but think large rollers were best; they cost more, but it was money well spent.

Another advantage was that the cane was under pressure for a greater length of time, the pressure commencing at a point further from the bite of the rolls, and the consequence was that the canes, when relieved, had not the same opportunity of soaking up the juice again, like a sponge, as the juice was kept a greater distance back from the extreme pressure of the rolls than was the case when the rolls were small. Therefore he thought the larger rolls had a better effect in extracting the juice; and they certainly gave more time for the juice to get away.

Then there was the question of the power required to reduce the cane. It was immaterial whether that operation was performed gradually or more quickly, if the reduction were the same. The work done was precisely the same in either case. There was, however, more surface of cane pressing against the large rolls than the small; hence the pressure on the bearings was greater, and—supposing the bearings were in proportion to the size of the rolls—the friction was a little increased.

One point should never be lost sight of in comparing the results of the different processes of manufacturing sugar, and that was the relative amount of fuel consumed in evaporating the juice. In the case of a very weak mill, only expressing 60 per cent. of juice instead of 70 per cent., there would be much more fuel in the megass in the form of sugar to evaporate the 60 per cent. of juice than there would be in the megass from which 70 per cent. had been expressed; and this lesser quantity of fuel would have the greater quantity of juice to evaporate. Taking these proportions, in the one case there were 129 units of fuel, and in the other 100 units of fuel, to evaporate a given quantity of juice.

With regard to the pumps, he thought that as a steady stream of juice was to be sent to the upper part of the mill, the centrifugal pump, with properly formed arms, was the best, as there was no churning up of the juice, or sending up air mixed with it; there were no valves to pass, and the juice would go up in a solid column.

The system of blowing steam in, notwithstanding its extensive use, seemed to him a very crude one, inasmuch as a certain quantity of water was thereby added to the juice, which had to be evaporated out again; to say nothing as to the objection of adding any water to raw juice.

With regard to the exact neutralisation of the acetic, sulphurous, and other acids in the juice, he thought hardly sufficient stress had been laid on this branch of the subject. If neutralisation was not perfect, a certain quantity of lime was carried away in the juice. It was well known to chemists that water with sugar in it would take up lime more readily than water without. Therefore it was important to have no excess of lime, as it would deteriorate the sugar, and 'fir' up the apparatus. He was very glad to hear that the sulphurous acid plan had been so well carried out, and that the clarification of the juice seemed to take place so satisfactorily, as it was a very great point to save the necessity of using animal charcoal, which was very expensive. It was important in neutralising any liquid, to see that the whole body of liquor in the pan was well mixed, or it could not be done accurately. The China clay, or whiting, appeared to be a good way of weighting the flocculent matter in the juice and carrying down the impurities.

With regard to the trays—as suggested by Mr. Knaggs—and carried out by Mr. Anderson, with the improvement of the nozzles and the addition of a little pressure—it seemed that the temperature could not be seriously injurious to the sugar. It was well known that good sugar could be made with ordinary pans exposed to a naked fire. If proper precautions were taken, he did not think that a steam temperature of about 290°, applied to the under-side of the pans, the juice being at 222°, was likely to do any serious injury in eighteen minutes.

There was actual proof that less molasses were made, because there was less burning by the temperature due to 3 lbs. pressure with the weak juice, and afterwards by the temperature of the vacuum pans, than there was with other processes. If any objection was still made to the 3 lbs. pressure, he would refer to the indicator diagram from the low-pressure engines (Plate 5); which showed that the steam was taken from the trays or concentrators, and used in the engine at a vacuum of 15 inches of mercury, so that the pressure of the steam in the cylinder was half a vacuum; and there might be that amount of vacuum in the concentrators, if desired, in which case the whole of the evaporation would take place under partial, though not perfect, vacuum. It was possible to do that, because the engine worked with so low a pressure; thus the juice might be under a partial vacuum the whole time.

In 1804, Richard Trevithick suggested the use of the steam from the juice being concentrated to work the steam engines.

Mr. Bramwell said the Paper embraced not only the bare facts relating to the manufacture of sugar and to the machinery employed, but also a statement of the principles on which the construction of the apparatus was based, and of the results obtained. It would afford data useful as well for other manufactures as for the particular manufacture under consideration. The Author had referred to some interesting facts in relation to the heating of water and of juice, showing the power of conduction under different circumstances. The question of heating might be divided into two branches: first, heating up to the point of ebullition, and secondly, heating after that point was reached.

From the results stated, it appeared that there were transmitted through each foot of surface per hour per degree of temperature of difference between the heating side and the side heated 260 units of heat, but that as soon as ebullition took place the power of transmission was raised to as much as 606 units; it further appeared that, when in the concentrator the juice was being dealt with, there was similarly a great difference in the power of transmission, namely, 219 units while the juice was being heated, and 521 units after ebullition had commenced.

Many years ago Mr. Bramwell was occupied about the combined vapour engine of Du Trembley, and, as that engine was a novel one, he had to make experiments to collect the requisite information. It might be in the recollection of the members who had heard the late Mr. J. W. Jameson's Paper "On the Performances of the Screw Steam Ship 'Sahel,' fitted with Du Trembley's Combined-Vapour Engine, and of the sister ship 'Oasis,' fitted with Steam-engines worked expansively, and provided with partial Surface Condensation,"[1] that in the combined vapour engines the condensation of the water steam of the first cylinder was effected by surrounding the condensing surfaces with ether, which, in condensing the water steam, became itself evaporated for use as an ether steam in a second cylinder. Mr. Bramwell's experiments had been directed to the determination of the amount of surface required for the condensation of the water steam and also for that of the ether steam, and in the course of these experiments it was found that great effect was produced by using ether as the surrounding medium for surface condensation: this great effect no doubt arose from the fact that the ether was itself evaporated while it condensed the steam. He was not able to lay before the meeting the exact results of those experiments, but they were entirely corroborative of those given in the Paper. Last April he had occasion to make experiments upon the rate of heating and evaporation that could be obtained under varying steam pressures in a jacketed copper pan that contained 100 gallons up to the working level, and had to the same level 25 square feet of heating surface. He tried first with steam at 5 lbs., then with 10 lbs., then with 15 lbs., and finally with 20 lbs. above atmosphere. With 5 lbs. pressure, from the temperature of 58°, at which the water was put in, up to 200°, the transmission of heat per 1° of difference of temperature between the steam used and the water that was being heated—the temperature of that water being taken every five minutes—was (in units) 161, 151, 176, and 160, the variations being no doubt due to some inaccuracy of observation; but from a temperature of 200° to 212° the rate of transmission went up to 327 units; while when ebullition commenced the rate of transmission increased at once to 427 units. With steam at 10 lbs. above atmosphere, the rate of transmission while heating up to the boiling point per 1° of difference of temperature and per superficial foot per hour was 186 units of

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xviii., p. 233.

heat, and, after ebullition commenced, was 435 units. With steam at 15 lbs. above atmospheric pressure, the transmission after ebullition commenced was 458 units: unhappily at this pressure there was a failure to record the transmission prior to ebullition. And lastly, with steam at 20 lbs. above atmosphere, the rate of transmission appeared to be 205 units before ebullition and 488 units after ebullition. Taking the average, he might say that from cold water up to about 200° the rate of transmission was 162 units, close upon the boiling point 327 units, and at and after the boiling point was attained 427 units. These figures were not so high as those given by the Paper before the meeting, but the pan he used had been erected for eight or nine years, and probably the surface of the copper on the steam side was incrusted with deposit. He believed if the material had been new the results would have shown other figures, and would have brought them up to the level of those in the Paper; but as it was, the rates of transmission recorded corroborated the fact of the enormous increase of conduction the instant evaporation began.

It had been suggested by Mr. Anderson that the greater rate of transmission was due to the increased circulation of the water when ebullition began; but Mr. Bramwell doubted if that could be so. Whether the water were stagnant or not, he thought there was abundant proof in the experiments themselves that the temperature of the film next the skin of the vessel must be practically that of the bulk of the water, the proof being that, taking the temperatures of that bulk as the basis for the calculation, such a very uniform rate of transmission per 1° of difference of observed temperature was obtained. Now, it seemed to him, this would not be the case if, owing to the water being comparatively stagnant, the film next the skin became much more highly heated than the bulk of the water, and was not, therefore, as competent to receive further accessions of heat as it would be if the water were in rapid motion. The consideration of these facts led him to believe that the cause of the more rapid transmission of heat after ebullition commenced could not be due to the comparative non-mobility of the water before that time. On these grounds, he did not think the theory of Mr. Anderson was the right one, although he was not prepared to substitute another for it.

Mr. W. Knaggs, in explanation of his previous remarks as regards the rollers employed in the Aba mills, said, that he did not object to the large size of the rollers; on the contrary, he agreed that large rollers crushed cane better than small ones, but the insufficient pressing of the cane was the result of other mechanical imperfections connected with the mills, which were, in his opinion, susceptible of improvement. At the same time he thought the advantage derived from the use of such heavy rollers and complicated gearing—notwithstanding the increased quantity of juice expressed—would not compensate for the extra cost and power required to work them.

With regard to the permanganate of soda, twelve months ago Mr. Ogston expressed some doubt as to the system, on the ground that the permanganate of soda might act as an oxydizing agent, and convert the sulphurous acid into sulphuric acid. Accordingly, some canes were brought from Egypt, and a series of experiments were made at Erith, by clarifying the juice with sulphurous acid, lime, clay, and permanganate of soda. The result was highly successful; he had a letter from Messrs. Easton and Anderson, expressing satisfaction with it; and subsequently 20 tons of permanganate of soda were sent out to Egypt, at an expense to the Viceroy of £1,600. He was, therefore, greatly surprised to hear Mr. Ogston say he knew nothing about the use of permanganate of soda at Aba. His son, who had charge of the clarifying at that place, was present, and he could testify that in every case there was a small addition of that substance. When the canes were of good quality, no doubt perfect clarification could be effected with sulphurous acid and lime alone; but the cane in Egypt was so inferior last season, that good clarification could not be obtained without permanganate of soda. It was not likely to produce sulphuric acid, because the sulphurous acid was neutralized with lime before the permanganate was applied, and it could only therefore convert the sulphite of lime thus formed into sulphate of lime; but even if it had been added to the juice prior to the neutralization of the sulphurous acid, and did convert it into sulphuric acid, the latter would have been immediately neutralized by the soda set free, and sulphate of soda would have been formed. He did not, therefore, think there was any danger on that score. He maintained that the description given in the Paper did not represent the process as performed at Aba. He started the mill, and left three days before the crop was over, while his son remained to finish the work.

Mr. G. H. Ogston observed that the effect of animal charcoal upon cane juice had been sufficiently studied to admit of defining the limits within which it could be economically employed, and of proving that although it would remove colour from vegetable solutions more perfectly than any known substance, it would not remove the objectionable nitrogenous compounds in cane juice which were precipitated by some other means. As far as he knew, it was the universal experience, that dilute solutions of cane sugar, before or after treatment with animal charcoal, required to stand but a very short time, even at the ordinary temperature of this climate, before chemical change set up. In the whitest samples exhibited of finished sugar there was absolutely no inverted or uncrystallizable sugar, because they had been steamed in the centrifugal machine, whilst the darker ones were simply washed with dilute sirup. In those that retained a tinge of colour, there might be, perhaps, 0·5 per cent. of uncrystallizable sugar attached mechanically to the crystals; the fact being that the uncrystallizable sugar remained in solution in the sirups, when they were concentrated to a point far beyond that ever reached in a sugar factory. It therefore passed through the centrifugal machines, and constituted, after the last boiling, molasses, a product which was usually sent to the distillery for conversion into spirit. Even when concentrated to the condition of treacle, the sirup still failed to deposit inverted sugar, so that there was no possibility of any remaining with the first white products. The samples upon the table contained, in fact, more than 99 per cent. of actual crystallizable sugar.

The action of sulphurous acid upon cane-juice was two-fold. First, it precipitated—in the form of flocculencies—gluten, colouring, mucilaginous and other kindred complex substances containing nitrogen, and thus was more effective than lime alone. Secondly, it arrested the change which the substances still left behind—including sugar itself—were so prone to undergo, in regard to colour. It was the uncrystallizable sugar which more easily became darkened by the effect of heat alone; and as by the sulphurous acid process the colour of the sirups, when they arrived at the vacuum pan, was much less than by the ordinary mode, it seemed one proof that not only was the original colour of the juice removed by its agency, but that the easily-coloured inverted sugar was not produced during the concentration in nearly such large quantity as when the ordinary mode of defecation was used. Reference had also been made to the quantity of sulphurous acid required to produce the desired effect. It was extremely small, but the minimum amount had not yet been accurately arrived at, because the arrangements for distributing the gas were not so perfect as they have since been made. This point had not hitherto received the attention it demanded. He believed that not more than $\frac{1}{10}$ lb. of sulphur per 500 gallons of fluid would now be required—in all probability

½ lb. sulphur to the first ton of sugar would be sufficient. A misunderstanding had taken place as to the Author's meaning when he referred to the power of cane juice to absorb 35 times its volume of sulphurous acid gas. It was of course meant to indicate the extreme ease with which the gas could be applied, owing to the readiness with which it was taken up, and that precautions were in reality necessary to prevent its too rapid absorption by the juice.

Cane juice was so delicate a material to deal with, that no doubt the same watchful care should be bestowed upon its treatment with sulphurous acid as was taken with lime or other defecation ; and the means for its exact regulation were in the present arrangement at hand. This was not entirely the case last season ; and he believed that had there been more perfect control in this respect, better results would have been obtained.

It had been remarked that the samples on the table were none of them really white sugar, although they appeared to be so, and that on comparing them with English loaf sugar, it would be at once seen that they had a greyness of tint. There would seem to have been a misunderstanding as to what the Author meant to convey. There was no idea, Mr. Ogston believed, and certainly it was not his opinion, that sugar, as white as best English loaf sugar, would ever be economically produced, at one operation, from cane juice ; and, at present, he did not think that sulphurous acid would take the place of animal charcoal in the second or refining process ; but what was contemplated by the advocates of the sulphurous acid mode of treatment, was to produce as good results in weight and colour from cane juice direct as could be obtained by the use of animal charcoal, but at a much less cost. This had been more than accomplished at Aba, its produce being compared with that of Bene Mazar, which, in the same locality and under similar conditions, was excellently worked on the French mode and with animal charcoal.

He concurred with the Author, in attributing the success at Aba to the mill having been arranged from the beginning, with reference to sulphurous acid treatment; and he looked for better results when some small improvements, suggested by the experience of last season, were made in the gas apparatus.

It appeared that great diversity of opinion existed upon several of the more important questions that had been raised. It had been said that the best results could not be obtained in evaporating vessels in which the thermometer rose above 150° or 160° ; and, on the contrary, it had been stated that the best sugar was only produced on estates on which the first evaporations took place in open pans over the naked fire; and he believed that the different results obtained in different places, by nominally the same process, were sufficient to justify a great diversity of opinion. The truth was, the extremes of the two conditions mainly tending, in properly defecated juice, to degrade sugar during the concentration of its solutions, were almost equally to be avoided; they were long exposure and excessively high temperature. Within certain limits, one of these evils was as destructive as the other; but they could not be very well considered apart, because, so long as the sirup was not too dense to circulate freely, a point approaching a high temperature might be reached at which the minimum amount of harm would be done, owing to the rapid evaporation it produced in a skilfully constructed apparatus.

Of course, if the question was broadly put, "Is it desirable to expose cane juice to a high temperature?" the answer must be in the negative. If, on the other hand, it were asked, "Would the evaporation occupy a long time?" the answer in the negative must be quite as decided; but as, in the present condition of the manufacture, a loss, by the production of uncrystallizable sugar, must be sustained, the machine to be sought for was an evaporator that would do the least harm in either direction. In the tray which the Author had described, it seemed that this result had been more nearly arrived at, than in any form of evaporator with which he was acquainted. The evaporation was extremely rapid, each particle of sugar being exposed for not more than 15 minutes or 20 minutes, and the temperature could under no circumstances rise above the boiling point of the solution, regard being had to the slight pressure maintained.

In any apparatus in which a much higher temperature was employed, although the evaporation might be more rapid, the danger of destruction by burning was unduly increased by the violent ebullition which took place, giving rise to the formation of large bubbles, which might leave portions of the heated surface dry, although but for an instant of time. He arrived at this opinion from investigations made some years ago on the rapid concentration of another organic solution, when the change which took place was shown to be much greater than was due to the general temperature of the liquid. It seemed that in the case of moderately dense solutions there was a liability of some portions of the substance dissolved being exposed, when the boiling was very violent, to a temperature nearly approaching that of the surface with which it was in contact. In the case of the evaporating tray, this temperature was limited to that due to the steam pressure in the lower part of the apparatus, and the boiling was not so violent as to create much risk from that cause.

The figures the Author had laid before the Meeting were the result of a number of observations recorded by five independent observers, and this showed the success that had attended the arrangements at the Aba factory. The process of sugar-making could not, however, be said to be in a satisfactory condition, whilst so great a loss—in the shape of degraded sugar—was admitted to be necessary. Practically, the whole of the sugar in the crystallizable form was found in the juice as expressed from the canes; and during the short time it was under treatment from 5 per cent. to 25 per cent. was degraded into uncrystallizable sugar. In scarcely any other manufacture would such a loss be submitted to, and he believed it would not be long before much more satisfactory yields were obtained. Meanwhile, he thought that the arrangements at Aba were an important advance in the interests of sugar manufacturers, and that eventually their advantages would be recognised.

He had already expressed his conviction that permanganate of soda was not used during the time his experiments were in progress. He, however, knew that it had occasionally been added to the cane juice before he went out to Egypt, and he attributed its discontinuance to his frequently expressed disapproval. His belief was, that it was not used during his observations. He was many times a day on the clarifier stage in the course of his experiments, and he never saw it once used, and, therefore, for a great proportion of the time, he knew it was not used. There were also four gentlemen engaged in making the observations, one or other of whom was on the stage night and day, and no report had been made to him of its use. He was, however, quite satisfied that Mr. Knaggs believed his son, who had charge of the clarification, did use it. Permanganate of potash was an oxydizing substance of the most active character, and, besides yielding oxygen most readily to sulphurous acid, converting it into sulphuric acid. It would add a soluble alkaline salt—manganate of soda—to the sirup, and it was agreed by sugar refiners that any salt of that character would destroy five times its own weight of crystallizable sugar. For those reasons, he was opposed to the use of permanganate of soda as a defecator, and, at the best, he considered its use extremely dangerous.

Mr. John Dixon said that he had been in Egypt and had seen the machinery described in the Paper, and could bear testimony to its excellence; but he could not help thinking that the Khedive, in spending so large a sum in the construction of such works, was really expending the national resources without any prospect of an adequate return. Egypt was strictly a producing country. It always had been so, and in no period of its history had it ever been distinguished for its manufactures. Those who were acquainted with the Egyptians of the present time would support him in saying they were not adapted for the pursuit of mechanical or manufacturing operations. It was not reasonable to suppose that they could succeed in such an enterprise when competing with the inhabitants of Great Britain, France, or Germany, where the manufacture and refinement of sugar was carried out to the greatest perfection. Sugar refining would not be more successful in Egypt than it had been in the East Indies, where it proved an entire failure; and he ventured to predict that a similar fate would attend this enterprise.

Mr. H. Davy, through the Secretary, remarked, that during the discussion of the chemical view of the manufacture of sugar some points were raised on which it was desirable some additional information should be given. He would ask whether in the sulphurous acid process the acid precipitated the gluten and other nitrogenous bodies present in the juice after expression from the cane? or were the foreign bodies precipitated by the boiling as scum, and the sulphurous acid used merely as an antiseptic and bleaching agent?

Some question had arisen with regard to the solubility of sulphurous acid in water, or solution of juice; the fact was, that the amount varied with the temperature; water at 0° centigrade absorbed 69 volumes, at 10° centigrade 51 volumes, at 20° centigrade 36 volumes.

It had been stated that permanganate of potash improved the crystallization and colour of sugar. That chemical compound was a powerful oxydizing reagent, and was used in Condy's fluid as a disinfectant, so that its action would probably be just the reverse of that desired, and cause the formation of other products than sugar; and if any sulphurous acid were present in the solution, sulphuric acid would be formed which would destroy the sugar. Experimentally, it might be possible to obtain favourable results, provided all the sulphurous acid were eliminated previously to the use of the permanganate, for if the organic colouring matter were more easily oxydable than sugar, then it would be oxydized and destroyed.

The action of animal charcoal in purifying sugar might be easily observed, but was difficult to understand. Some chemists stated that the nitrogen held by the charcoal was the cause of the purifying action; others that it was effected by galvanic action, and others by absorption; but possibly the presence of phosphate of lime was the immediate cause, as charcoal which contained that compound acted more efficiently than charcoal without it. In the manufacture of sugar from the beet-root, a large quantity of calcic hydrate was used, far more than was needed to neutralize the acid present in the juice. Why so much was used he did not know—the juice containing the lime was boiled, and the scum removed. The compound of lime and sugar was not so easily acted on by heat as sugar in its pure state. After the scum was removed, carbonic acid was passed through the solution; the lime was deposited as carbonate, leaving the sugar to be concentrated. The sugar derived from the beet-root and that from the cane had the same composition and, he believed, the same chemical constitution. He did not consider lime to be inimical to sugar. Generally, all acids destroyed sugar, bases did not; but that proposition must not be taken as absolutely true, as the more alkaline the base, the less action it had upon sugar—thus potash had less action than lime.

There were other methods of purifying sugar which were simple in principle; but he was unable to state whether they had been tried on a large scale. When baryta was added to cane juice a precipitate was formed, consisting of an insoluble compound of baryta and sugar. The impurities remained in the solution. If this precipitate was separated from the solution by filtration and washed and then suspended in water, a stream of carbonic acid passed into the water would precipitate the baryta as a carbonate and leave the sugar in solution. Another method was to add the subacetate of lead to the cane juice; this carried down all the impurities as a precipitate leaving sugar in solution; the addition of sulphurous acid caused excess of lead to be precipitated as sulphite; the lead was so completely removed that no trace of it could be found. It was stated by chemists that sugar prepared after the old method contained far more lead than was obtained in this way. He trusted that some information would be given to the Meeting, with regard to these two methods of preparing sugar, and if such there were, the difficulties of their being carried out on an extensive scale.

As regarded the mechanical arrangements, he considered that, unless under very exceptional conditions, a vacuum pan should not be converted into a boiler. Supposing the pressure of steam to be 3 lbs. on the square inch, the temperature would (approximately) be raised to 91° Fahrenheit above boiling point at atmospheric pressure. The increase of temperature and the longer exposure to heat would of course increase the proportion of uncrystallizable sugar. It was well known that the more rapid the concentration and the lower the temperature the less amount of sugar would be decomposed.

Mr. D. Halpin remarked that the extra gearing in the machinery was probably introduced to modify strains which really did not exist. As far as he was aware, the old arrangement of three wheels had been found to answer all purposes. He believed there was no strain on the pinions, and when the top roller was running the others were driven as friction rollers. The difference in the width between the rollers had no effect upon the strain on the pinions. The driving wheel was 2 ft. 6 in. from the centre of the pinion, and he thought that mode of construction should have been avoided. The principal reason why rolling mills broke down was because they were connected by a mass of loose and insufficient framing. If they were put upon one frame, and that sufficiently rigid, accidents of that nature would not occur. Rolling mills were also frequently unequally set up, or in a direction in which the rollers were not parallel, and, with careless feeding, accidents took place. He thought the seven-wheel gear was preferable to the gearing adopted in the Aba factory, involving ten wheels besides extra shafts.

An opinion had been expressed that the mill should be placed above the clarifiers and that pumping should be dispensed with. He considered the centrifugal pump was the best, but that the cane mill should be placed high up, and the juice collected by gravitation. The use of the 'montejus' was very troublesome, but that of the ordinary cane pump was worse.

With respect to clarification, there were two systems—one by fire and the other by steam. The former was very old, and was seldom now used. It could not, he conceived, be advantageously used, owing to the fact, that the heat could not be stopped at the right point. There were two subdivisions of steam clarification —one high pressure and the other low pressure. High pressure was used in two systems. The French system, with a mass of pipes swung on trunnions on one side of the clarifier, was very complicated and difficult to clean. In the other system, steam jackets were used as in the Aba factory. He could not see the use of high-pressure clarification; low pressure was, in his opinion, preferable, if the steam was taken directly out of the engine. As a rule, if the sirup ran full from the mill the scum was cracked by the heat of the waste steam from the engine as soon as the clarifier was filled.

It had been stated that the juice was boiled in the clarifiers at the Aba factory; he could not see any advantage gained by that practice, because, as the juice was boiled, the dirt in the liquor would become less capable of separation. The old low-pressure clarifiers, where all the steam was obtained from the engine, were much preferable to the high-pressure system. In the evaporating arrangement in use at Aba there was only one advantage, and that a slight one, namely, the juice was practically kept at a constant temperature. There was no advantage derived from evaporating under pressure, and he thought that with the pans used there it would be troublesome to keep the work going on. If they ceased running from any cause, and if the sugar got jammed in at one end, the result would be serious. The economy of working engines with 3 lbs. to 6 lbs. of steam was very questionable. He had seen much better sugar than that exhibited made in the old way, evaporated under atmospheric pressure and at a moderately low temperature.

There were two points in connection with the centrifugal machines which, he thought, were open to objection. One was that the whole of the centrifugals were connected together and driven by one shaft, and put in motion by some kind of friction gearing. That system had been largely tried, but he thought it was surpassed by the direct driven centrifugals, which start easily with a load without causing belts—as they were apt to do—to slip or break. He thought, with centrifugals of 40 in. to 48 in. running 1,200 revolutions to 1,500 revolutions per minute, third sugars might be cured as fast as they were made without being obliged to store them in the 196,000 gallon tanks provided outside the mill for that purpose, and also to avoid the necessity of washing, and thus destroying the grain of the first sugars. He would only remark further, that he could not see in the arrangement of the mill what advantage there was in keeping all the firing inside, and he did not see why the boilers and evaporating pans could not be ranged at right angles to their present position so as to get the firing outside the mill, which he thought would be a decided advantage considering the nature of the fuel—megass—and the temperature in the building, which must be almost tropical.

Mr. Anderson, in reply upon the discussion, said the discussion which had arisen upon the Paper had in a great degree neutralized itself, as several of the questions put and remarks made about different parts of the machinery had been answered by gentlemen quite as competent to deal with the subject as himself.

With respect to the percentage of juice expressed, and the important relation that existed between the amount of fuel necessary for making sugar and the quantity of juice obtained, Mr. Cowper had fully explained the matter; and an interesting illustration was given to Mr. Anderson last week by one of the Engineers of the Colonial Company, who mentioned the case of a factory making sugar for years without using any coal at all; but where, after having put up a more powerful mill and strengthened the engine, they found, to their great astonishment, that they were obliged to use coal, inasmuch as with their stronger machinery they squeezed out more juice, and, consequently, left less fuel in the megass.

It had been stated that it would have been better if larger tubular clarifiers, and low-pressure steam had been used. Plain spherical clarifiers had been preferred to tubular ones, on account of the facility of cleaning and thoroughly mixing the lime and gas. With regard to low-pressure steam, there was no objection to its use, except in respect of time, the great object being to get the clarifiers to boil as quickly as possible.

Much altercation had taken place as to whether permanganate of soda had been used or not. He would say, from his personal observation on the clarifying stage, that he had seen many clarifiers let down without permanganate of soda having been added; and Mr. Knaggs had told him he only thought it was necessary with exceptionally bad juice. Chemists were so much agreed as to the pernicious effects of the salt that its use had been interdicted for the future.

The concentrators had been objected to on account of the high temperature due to working under pressure. This objection was perfectly valid; and if coal were not a matter of very important consideration, he should prefer concentrating the juice 'in vacuo.'

A mathematical law had been laid down by Mr. Alliott for expressing the injury done to the juice by time and temperature, to the effect that, taking 140° as the starting point, any greater temperature injured the juice as the square of the increase of temperature, and as the time. Assuming the concretors to do at 214°, and in ten minutes, what the Aba tray performed at 230°, in eighteen minutes, it followed that the latter must injure the sirup over $2\frac{1}{2}$ times more than the former. But Mr. Alliott had not said how this measure was to be applied. Let it be supposed that the percentage of molasses was the best test of the condition of the sirup, and then see how the formula worked in practice. The two Australian mills, referred to in the table,[1] both used concretors, the one in conjunction with a vacuum pan, the other with a Wetzel pan, both also using animal charcoal. Neither of them made white sugar, but they produced from 41 per cent. to 48 per cent. of molasses; whereas the Aba factory produced only 34 per cent. But it might be urged that the conditions of soil and climate were not the same, and that the comparison would not be fair on that account. Then let Aba be compared with Bene Mazar. The two factories were within 6 miles of each other, the canes and soil the same, and the management identical. In the latter mill the concentration was performed in triple-action concentrators 'in vacuo,' at a mean temperature of 170°, in 105 minutes; and therefore Aba should make $1\frac{1}{2}$ more molasses, whereas it only made $\frac{6}{10}$ths. He must, however, do Mr. Alliott the justice to say, that he had since informed him by letter that, though he had the greatest confidence in the formula he had propounded, he was not the author of it, and believed it was arrived at from vacuum-pan experiments, at a time anterior to the invention of the concretor. He therefore thought Mr. Alliott was a little venturesome in trying to impose the law on the Aba concentration, especially as he had Mr. Anderson's table of comparative production to test his formula by.

With regard to the statement made by Mr. Knaggs, that he was the author of the process, and designer of the factory, Mr. Anderson had already expressed his regret that, in curtailing the Paper for reading, the introductory paragraphs, in which Mr. Knaggs' name was mentioned, were omitted. It was a purely accidental omission, and he repeated what was stated in the Paper, namely, that the process of defecating cane-juice by means of sulphurous acid gas and other ingredients, combined with rapid concentration, was first introduced to his firm by Mr. Knaggs; but he thought the discussion had clearly shown that, with the exception of the cane-mill gearing, which Mr. Knaggs certainly did not invent, there was nothing new in any of the appliances, or in the use of sulphurous acid. The factory was designed while Mr. Knaggs was in Jamaica, and without any assistance from him; and when he came to England, in 1870, Messrs. Eastons and Anderson had already commenced shipping the machinery. It was quite true that Mr. Knaggs protested strongly against several of the arrangements made, but Mr. Anderson had disregarded most of his objections; and to his firmness in that respect he attributed, to some extent, the success of the factory.

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[1] *Vide* ante, p. 64.

In conclusion, he must say he had not brought this Paper before the Institution as a collection of new inventions; he merely claimed to have combined apparatus more or less known in such a manner, as to make a process hitherto unsuccessful a complete success. Not one of the experienced gentlemen who had spoken had challenged the accuracy of the table of comparative yields of different systems, nor had superior results been brought forward. These, after all, were the tests, when combined with economy of first cost and of working, by which the process should be judged.

December 3, 1872.
T. HAWKSLEY, President,
in the Chair.

The following Candidates were balloted for and duly elected :—Robert Edward Forrest, William Hall, John Skardon Heyman, Robert Morton, and Henry Robert Waring, as Members; Samuel Abbott, John Addy, Stud. Inst., C.E., John Aiton, John Romilly Allen, Crawford Peter Barlow, B.A., Stud. Inst., C.E., William Adamson Barron, George John Burke, John Montriou Campion, Stud. Inst. C.E., William Henry Clemmey, William Griffin Davis, George Frederick Deacon, Francis Henry Evans, Richard Thomas Hall, Edward Westley Jacob, Ailsa Janson, Frederick John Johnstone, William Benjamin Leggatt, Evan Leigh, Alfred David Lewis, Major John Frederick Adolphus McNair, late R.A., Edward John Theodore Manby, Thomas Thomas Marks, Captain James Law Lushington Morant, R.E., Lieut. William Gustavus Nicholson, R.E., Wellesley Innes Noad, Stud. Inst. C.E., Francis William Otter, Alexander Payne, William Pelham Richardson, James Robertson, Alexander Manson Rymer-Jones, Charles Edward Shepheard, Rupert Turberville Smith, Arthur Southam, Thomas Samuel Speck, John Alfred Stockwell, Henry Tivy Tomkins, Frederick Robert Upcott, Griffin William Vice, James Henry Waller, Stud. Inst. C.E., Edward Bentinck Williams, Corbet Woodall, Henry Robert Woolbert, as Associates.

It was announced that the Council, acting under the provisions of Sect. III. Cl. 7, of the Bye-Laws, had transferred John Howkins, jun., and Francis William Webb from the class of Associates to that of Members.

Also, that the following Candidates, having been duly recommended, had been admitted by the Council, under the provisions of Sect. IV. of the Bye-Laws, as Students of the Institution:—Thomas Blair, George Dundas Churchward, Arthur Osbert Cooper, Matthew Curry, jun., Thomas Elmitt Curry, Percy Rigden Dix, Bernard William Flatt, Gustave Adolphe Haas, Frederick James Leigh, Boswell Parkinson Milsom, George Phillips Mulock, Charles Edward Pickford, John Wallis Shores, John Smith, Richard John Symonds, and Herbert Charles Erskine Vernon.

The discussion upon the Paper, No. 1,349, "On the Aba-el-Wakf Sugar Factory, Upper Egypt," by Mr. W. Anderson, was continued throughout the evening.

December 10, 1872.

T. HAWKSLEY, President,
in the Chair.

The discussion upon the Paper, No. 1,349, "On the Aba-el-Wakf Sugar Factory, Upper Egypt," by Mr. W. Anderson, was continued throughout the evening, to the exclusion of any other subject.

[Annual General Meeting.

ANNUAL GENERAL MEETING.

December 17, 1872.

T. HAWKSLEY, President,
in the Chair.

The list of members nominated as suitable to fill the several offices in the Council was read.

Messrs. C. Frewer, H. Hayter, R. C. May, W. Shield, T. M. Smith, Joseph Taylor, and A. Williams, were requested to act as Scrutineers of the Ballot, for the election of the President, Vice-Presidents, and other Members and Associates of Council for the ensuing year; and it was resolved that the ballot papers should be sent for examination every quarter of an hour that the Ballot remained open.

The Ballot having been declared open, the Annual Report of the Council, on the proceedings of the Institution during the past year, was read. (*Vide* page 112.)

Resolved,—That the Report of the Council be received and approved, that it be referred to the Council to be arranged for printing, and that it be circulated with the Minutes of Proceedings in the usual manner.

Resolved,—That the thanks of the Institution are due, and are presented to Messrs. R. C. May and J. Wolfe Barry, for the readiness with which they undertook the office of Auditors of Accounts; and that Messrs. J. Wolfe Barry and W. Lloyd be requested to act as Auditors for the ensuing year.

Mr. Barry returned thanks.

The Telford Medals, the Telford and Manby Premiums of Books, and the Miller Prizes, which had been awarded, were presented. (*Vide* pages 114—115.)

Resolved,—That the thanks of the Institution are justly due, and are presented to the Vice-Presidents and other Members of the Council, for their co-operation with the President, their constant attendance at the Meetings, and their zeal on behalf of the Institution.

Mr. Harrison, Vice-President, returned thanks.

Resolved unanimously,—That the cordial thanks of the Meeting be given to Mr. Hawksley, President, for his strenuous efforts in the interests of the Institution, for his extraordinary attention to the duties of his office, and for the urbanity he has at all times displayed in the Chair.

Mr. Hawksley, President, returned thanks.

Resolved,— That the cordial thanks of the Meeting be given to Mr. Charles Manby, the Honorary Secretary, and to Mr. James Forrest, the Secretary, for their unremitting and zealous services on behalf of the Institution and of the profession.

Mr. Manby and Mr. Forrest returned thanks.

The Ballot having been open more than an hour, the Scrutineers, after examining the papers, announced that the following gentlemen were duly elected:—

President.

THOMAS HAWKSLEY.

Vice-Presidents.

John Frederic Bateman, F.R.S.
Thomas Elliot Harrison.
George Willoughby Hemans.
George Robert Stephenson.

OTHER MEMBERS OF COUNCIL.

Members.

James Abernethy.
Sir W. G. Armstrong, C.B., F.R.S.
William Henry Barlow, F.R.S.
Joseph William Bazalgette, C.B.
George Berkley.
Frederick Joseph Bramwell.
George Barclay Bruce.
James Brunlees.
Sir John Coode.
Charles William Siemens, F.R.S.
Sir Jos. Whitworth, Bart., F.R.S.
Edward Woods.

Associates.

David Forbes, F.R.S. James Timmins Chance, M.A.
James Grierson.

Resolved,—That the thanks of the Meeting be given to Messrs. Frewer, Hayter, May, Shield, Smith, Taylor, and Williams, the Scrutineers, for the promptitude and efficiency with which they have performed the duties of their office; and that the Ballot Papers be destroyed.

[ANNUAL REPORT.

ANNUAL REPORT.

Session 1872–73.

Since the last Annual Meeting, the Council then elected to conduct and control the business of the Institution have been mainly occupied in following in the footsteps of their predecessors, by whose exertions the Society had been brought to a most flourishing condition—a condition which the details to be furnished in this Report will show has been well sustained during the past year.

One of the matters which first engaged attention was the decoration of the building, the walls of which had not been considered sufficiently dry, since the enlargement of the premises, to admit of this work being satisfactorily accomplished at an earlier period. The Architect, Mr. Thomas H. Wyatt, the President of the Royal Institute of British Architects, and an Associate of this Institution, was requested to mature plans for the purpose. The studies he produced, and the recommendations he made, led the Council to intrust the execution of the works to Messrs. J. G. Crace and Son, by whom they have since been successfully carried out. The meeting-room is the only part in which coloured decoration has been attempted, and the architectural treatment of that room rendered it by no means an easy problem; for, in view of the possible contingency of having at some future period to provide galleries at the ends of the room, the Architect had introduced two distinct orders. The use of cloth in the lower compartments of the walls of the meeting-room has contributed to subdue the resonance from the hard surface of the parian cement, and has sensibly improved its acoustic properties. On the first-floor landing a niche has been specially constructed to receive a cast of the statue of Telford, by Bailey, as erected in Westminster Abbey. This cast is the gift of Mr. Frank James, Assoc. Inst. C.E., and is a most appropriate present, Telford having, as is well known, taken great interest in the Society from its foundation, having occupied the Presidential Chair from 1820 to 1834, and having made a handsome bequest to the Institution.

The alterations effected during the vacation have included a great addition to the book-shelf accommodation in the Library. This addition was rendered necessary by the recent large accessions,—by presentation, by bequest, and by purchase. It is thought that provision has now been made for the next six or seven years, on the supposition that the present rate of increase continues. Among the more important acquisitions are a complete set of Dingler's "Polytechnisches Journal," extending from 1820 to the present time; the "Journal of the Royal Asiatic Society of Bengal;" "Papers on Practical Engineering," published by the Engineer Department of the United States Army; a set of Papers and Drawings descriptive of the Public Works of New Zealand; and a choice series of books, principally on Naval Architecture, which the Institution was permitted to select from the Library of the late Mr. Andrew Murray, C.B., M. Inst. C.E. The Parliamentary Papers referring to Public Works have been completed, classified, and bound in volumes, thus making the information more readily accessible. The Library now contains about eleven thousand volumes, almost exclusively relating to mechanical science and engineering, and, as a technical collection, devoted to a special subject, it is believed to be unrivalled.

The topics discussed at the Ordinary Meetings may be thus summarized:—On the Employment of Pneumatic Despatch Tubes on the Circuit system, for the conveyance of Telegrams, Letters, and light Parcels in Cities and Towns; an investigation into the Stresses of Rigid Arches, continuous Beams and curved Structures; a description of the Somerset Dock at Malta; on the Value of Water and its storage and distribution in Southern India; an account of the Bridge over the Gorai River, on the Goalundo Extension of the Eastern Bengal Railway; on the Kind-Chaudron system of sinking shafts through water-bearing strata without the use of Pumping Machinery; on the Soonkêsala Canal of the Madras Irrigation and Canal Company; on the Conditions which favour, and those which limit, the Economy of Fuel in the Blast Furnace for Smelting Iron; a description of the new South Dock in the Isle of Dogs, forming part of the West India Docks; the Pumping Machinery at Lade Bank, for the Drainage of the fourth district of the River Witham; on the Construction of Heavy Artillery, with reference to Economy of the mechanical forces engaged;—and on Explosive Agents, as applied to Industrial Purposes.

From this enumeration it will be seen, that there has been an opportunity of eliciting opinions on various branches of practice; and a reference to the two volumes of "Minutes of Proceedings," issued during the recess, will show that many members availed themselves of the opportunity to place on record their views and experience on these several matters.

The Council have awarded the following Telford Medals and Premiums, and Manby Premium, to the Authors of some of these communications:—

1. A Telford Medal, and a Telford Premium, in Books, to Bradford Leslie, M. Inst. C.E., for his "Account of the Bridge over the Gorai River, on the Goalundo Extension of the Eastern Bengal Railway."
2. A Telford Medal, and a Telford Premium, in Books, to Carl Siemens, M. Inst. C.E., for his Paper on "Pneumatic Despatch Tubes: the Circuit System."
3. A Telford Medal, and a Telford Premium, in Books, to William Bell, M. Inst. C.E., for his Paper "On the Stresses of Rigid Arches, Continuous Beams, and Curved Structures."
4. A Telford Medal, and a Telford Premium, in Books, to John Herbert Latham, M.A., M. Inst. C.E., for his description of "The Soonkêsala Canal of the Madras Irrigation and Canal Company."
5. A Telford Medal, and a Telford Premium, in Books, to George Gordon, M. Inst. C.E., for his Paper on "The Value of Water, and its Storage and Distribution in Southern India."
6. A Telford Premium, in Books, to Frederick Augustus Abel, F.R.S., for his Paper on "Explosive Agents applied to Industrial Purposes."
7. A Telford Premium, in Books, to Bashley Britten, for his Paper on "The Construction of Heavy Artillery, with reference to Economy of the Mechanical Forces engaged."
8. The Manby Premium, in Books, to Charles Andrews, M. Inst. C.E., for his Paper on "The Somerset Dock at Malta."

In the adjudication of the Premiums, the communication of your Associate of Council, Mr. Isaac Lowthian Bell, on "The Economy of Fuel in the Iron Blast Furnace," was not taken into consideration, in accordance with a well-understood custom; but the thanks of the Institution are nevertheless eminently due to Mr. Bell for this valuable essay.

It is frequently necessary to ask the Authors of Papers to reduce them to such a length for reading as will allow time for those members and visitors who are prepared to offer remarks on the subjects brought forward to do so. Failing this, one of the primary objects of the Meetings—to provoke discussion—would be frustrated. A free and open debate must be possible on every occasion ; and this has, happily, hitherto been the characteristic of the Meetings.

There was also a short series of Supplemental Meetings, to enable the Students to read and discuss Papers among themselves. The Council have learnt with satisfaction, from the Members who kindly presided on these occasions, that they were favourably impressed with the value of such meetings to the Students, as being calculated to do a great deal of good. The policy of holding such meetings being established, it rests with the Students to turn them to the best account, by reading beforehand as much of the accessible literature on each particular subject as their time will allow. The Library of the Institution affords every facility for the purpose, and few perhaps are aware how much information is to be derived from the collection until they have made a search for facts on any given subject. The aptitude, the intelligent discrimination, the apparent sustained attention throughout, which are said to have characterized those taking part in and present at these proceedings, are evidences that in the future the Students will continue to exert themselves for their own individual improvement, as well as for the benefit of their fellow-Students. There are several ways in which this may be done, beyond the obvious plan already pointed out :—thus, the sketching of existing works, accompanied by critical remarks upon the peculiarities, the constructive skill, and the structural defects thought to belong to such works, could not fail to be a most useful exercise.

For the Papers submitted by Students, the following Miller Prizes have been awarded :—

1. A Miller Prize to Oswald Brown, Stud. Inst. C.E., for his Paper on "Sewage Utilization."
2. A Miller Prize to Arthur Turnour Atchison, B.A., Stud. Inst. C.E., for his Paper on "Railway Bridges of Great Span."
3. A Miller Prize to John Addy, Stud. Inst. C.E., for his Paper on "The most suitable Materials for, and the best mode of Formation of, the Surfaces of the Streets of large Towns."
4. A Miller Prize to Alfred Edward Preston, Stud. Inst. C.E., for his Paper on "Wood-Working Machinery."
5. A Miller Prize to William Patterson Orchard, B.E., Stud. Inst. C.E., for his Paper on "The Education of a Civil Engineer."

Mr. Hawksley, the President, in his inaugural Address at the commencement of the session, made some remarks on professional education. These were more particularly addressed to the Students, upon whom the importance was urged of becoming practically acquainted with the details of works in course of construction, and of not resting satisfied with theoretical knowledge alone. Carrying out this advice, he, in the course of the summer, invited the Students to visit the Leicester Water Works, one of the most recent constructions of the kind, and almost the only one which combines in itself the storing, the gravitation, and the pumping systems. Nearly eighty of the Students availed themselves of this invitation—a larger gathering of that class than had ever previously taken place. The President explained on the spot the objects of the undertaking, and described minutely the details of the several works, aided by an elaborate series of drawings, in themselves a fine example to the younger members of the profession. The warmest thanks of the Institution are due to Mr. Hawksley for the opportunity thus afforded to the Students of acquiring professional knowledge, as well as for the liberality with which the whole programme was conceived and carried out.

Earlier in the year Mr. Alexander Fraser, M. Inst. C.E., had kindly shown a party of the Students over the Chief Station of the Grand Junction Water-Works Company at Kew Bridge — a courtesy for which the unanimous thanks of the Council were tendered to Mr. Fraser.

As it should be the object of every member to aid in enriching the Proceedings of the Institution with the results of his professional experience and practice, attention has been directed, by Circular, to the list of Subjects for Papers, Session 1872–73 (page 128), in the hope that the members will, directly or indirectly, contribute, or assist in the contribution of, some communication for reading at the Meetings, or for publication in the Appendices to the volumes of "Minutes" hereafter to be issued. British engineering literature is still thought to be deficient in well-authenticated accounts of executed works in foreign countries. It has therefore been deemed expedient to include in the list a reference to various undertakings which have been carried out, or which are in progress, on the Continent of Europe and in the United States. Detailed particulars of such enterprises, especially when differing in design or in construction from similar operations at home, could not fail to afford valuable information.

Three additions have been made to the roll of Honorary Members, by the election of His Majesty the Emperor of Brazil, F.R.S., &c., &c., whose distinguished attainments in various branches of science, particularly in those connected with Civil Engineering, have been so generally recognized; of H.R.H. Prince Arthur, K.G., whose attention to the kindred art of military engineering is so well known; and of Dr. Percy, F.R.S., whose original researches, especially in connection with metallurgy, are eminently calculated to promote the advancement of many departments of knowledge on which the successful practice of the Civil Engineer depends.

The Emperor of Brazil and Prince Arthur have both intimated that they feel highly honoured by the compliment thus conferred upon them; while Dr. Percy has stated he regards the distinction as a proof that the results of his labours, during nearly thirty years, have met with the favourable consideration of British Engineers, and that he could neither desire nor expect a better reward.

The tabular statement of the transfers, elections, deceases, and resignations of the members of all classes of the Corporation, that is exclusive of the Students, during the years 1870–71 and 1871–72 (taking into consideration the names which have been erased from the Register), is as follows :—

Year.	Honorary Members.	Members.	Associates.	
1870–71.				
Transferred to Members	..	..	11	
Elections	..	26	102	128—45=83
Deaths	2	11	22	
Resignations	..	..	4	45
Erased from Register	..	1	5	
Members of all Classes on the Books, 30th November, 1871	14	724	1048	1,786
1871–72.				
Transferred to Members	..	..	17	
Elections	3	22	115	142—45=97
Restored to Register	..	..	2	
Deaths	1	9	19	
Resignations	..	1	9	45
Erased from Register	..	1	5	
Members of all Classes on the Books, 30th November, 1872	16	752	1,115	1,883

This represents a net effective increase of 97, or nearly 5½ per cent. during the last twelve months. Of the 752 Members on the Register at the date named, 549 were elected directly into that class, and 203 were transferred to it, either from the class of Associate or from the now abolished class of Graduate.

At the date of the last Report there were 203 Students attached to the Institution. In the session 1871–72, the Council admitted 63; while 26 were removed from the list, viz., 9 resignations, 1 erasure, and 16 elected into the Corporation as Associates—so that the net increase has been 37, making the total on the 30th of November last 240. This represents an addition at the rate of about 18 per cent. during the past twelve months. It may be mentioned, that since the Students' class was instituted, five years ago, 324 candidates have been admitted; of that number 36 have been elected Associates, 45 have resigned, 2 have died, and 1 has been erased from the list, leaving 240 still on the books.

The Institution has now been established nearly fifty-five years, having been founded on the 2nd of January, 1818. The elections into the corporation, and the numbers of the several classes still remaining on the books, are shown in the following Table[1]:—

Years.	Total Number of Elections in Periods named.	Numbers of such Elections still on the Books.			
		Hon. Members.	Members.	Associates.	Totals.
1818–22	59	1	1	..	2
1823–27	106	..	7	..	7
1828–32	104	..	8	..	8
1833–37	138	..	21	8	29
1838–42	313	6	37	44	87
1843–47	192	..	42	23	65
1848–52	247	..	56	59	115
1853–57	226	..	79	67	146
1858–62	309	1	118	126	245
1863–67	637	4	239	315	558
1868–72	693	4	151	512	667
Totals	3,024	16	759	1,154	1,929

In this return the 271 Students at present on the books (of whom 31 have been admitted during the current session) are not taken into consideration.

The deaths recorded during the year have been:—

Honorary Member: The Earl of Lonsdale.

Members: Nathaniel Beardmore, David Reid Edgeworth, Joseph Walter Gale, John Mortimer Heppel, Durand Kershaw, Andrew Murray, C.B., William Scamp, Richard Smallman, and Henry Johnston Wylie.

Associates: James Bagnall, Edward Banfield, Joseph Baxen-

[1] In this Table the elections and changes during the present month are included. Sec. Inst. C.E., December 17, 1872.

dale, John Van Norden Bazalgette, Edward Ladd Betts, Edwin Bidder, Charles William Dixon, Thomas Dunn, John Samuel Enys, Charles Haslett, Thomas Howard, Robert Jobson, Frederick Marrable, Edmund Morel, Christopher Pattison, Augustus Siebe, William Sykes, Robert Harry Inglis Synnot, and Arthur Valentine.

Since the books were made up the decease of Mr. Joseph Cubitt has occurred. This was communicated to the members at the last ordinary meeting, when a letter of condolence was directed to be addressed to the widow and her family. By the death of Mr. Cubitt the members have lost a valued friend, the Institution a respected Vice-President, the profession a distinguished Engineer, and society an honourable man.

The following members, having tendered their resignations, have been permitted to withdraw from the Institution:—Robert Roberts, *Member;* Charles William Robert Chapman, Richard Massey Greene, James Hall, William Harrison, John James Myres, Jun., Joseph Drown Rigby, Bernard Snow, William Weild, and John Bazley White, *Associates.*

Mr. Thomas Howard, who was for thirty-seven years an Associate, as an evidence of the interest he took in the Society, has bequeathed to it the sum of £500, free of legacy duty, which sum he has by will directed "to be invested, and the interest thereof to be applied in such manner and under such conditions and restrictions as the Council of the said Institution may think most expedient, for the purpose of presenting periodically a prize or medal to the author of a treatise on any of the uses or properties of iron, or to the inventor of some new and valuable process relating thereto—such author or inventor being a Member, Graduate, or Associate of the said Institution." The sum has already been received, and has been invested in the purchase of £551. 16*s.* 6*d.* New Three per Cents.

With respect to the financial position, the Auditors have ascertained that the receipts included in the abstract of accounts have been credited by the bankers, Messrs. Coutts and Co., and that the payments have all been made by the authority of the Council. From the statement of Receipts and Expenditure, attached to this Report, it appears that last year the income proper amounted to £6,574. 10*s.* 8*d.*, to which must be added for fees and building and publication funds on election and life compositions £1,294. 4*s.* 6*d.*, and for dividends on trust funds £411. 2*s.* 3*d.*, making together £8,279. 17*s.* 5*d.* On the debit side of the account, the disbursements (less received for "Minutes of Proceedings") have been

£5,221. 18*s.* 11*d.*, and premiums under trust £249. 18*s.* 9*d.* A sum of £2,908. 18*s.* 9*d.* has been invested (besides the Howard bequest) in the purchase of £1,338 London and North Western, and £1,500 North Eastern Railway Companies Four Per Cent. Debenture Stocks. It is necessary to add, to allow of a balance being struck, that the cash in hand is less by £108. 7*s.* 11*d.* than it was at the same period in 1871, and that a sum of £7. 8*s.* 11*d.* is due from the Benevolent Fund for petty cash expenses.

The following is a summary of the Receipts for the last two years :—

	1871.						1872.					
	£.	*s.*	*d.*	£.	*s.*	*d.*	£.	*s.*	*d.*	£.	*s.*	*d.*
From subscriptions, and sundries. .	5,592	9	0				6,034	3	0			
„ dividends on investments not in trust	430	0	0	6,022	9	0	540	7	8	6,574	10	8
„ Fees, Building and Publication Funds on election, and life compositions	. .			1,201	4	0	. .			1,294	4	6
„ dividends on Trust Funds . . .	. .			411	16	4	. .			411	2	3
Totals . .	. .			7,635	9	4	. .			£8,279	17	5

The Expenditure during the same period has been :—

	1871.						1872.					
	£.	*s.*	*d.*	£.	*s.*	*d.*	£.	*s.*	*d.*	£.	*s.*	*d.*
To disbursements, including Minutes of Proceedings (less repayment on that account) .	5,019	3	11				5,221	18	11			
„ New building .	214	13	10									
„ Premiums under Trusts (less repayment for extra cost of binding)	261	1	8	5,494	19	5	249	18	9	5,471	17	8
„ Investments:— Telford Fund (unexpended dividends) . . .	254	9	7									
Miller Fund (ditto)	408	0	4									
„ Howard Bequest.	. .			. .			500	0	0			
General account .	1,517	0	9	2,179	10	8	2,908	18	9	3,408	18	9
Totals . .	. .			£7,674	10	1	. .			£8,880	16	5

The Funds of the Institution consisted, on the 30th of November last, of—

I. General Funds.

		£. s. d.	£. s. d.	£. s. d.
Institution Investments:—				
Great Eastern Railway Four per Cent. Debenture Stock .		3,650 0 0		
London and North Western ditto		2,500 0 0		
London, Brighton, and South Coast ditto . . .		1,000 0 0		
North Eastern ditto . .		3,000 0 0		
Great Northern ditto . .		1,000 0 0		
Manchester, Sheffield, and Lincolnshire Railway Four and a Half ditto . . .		1,000 0 0		
London, Brighton, and South Coast ditto . . .		1,500 0 0		
New Three per Cents. . .		1,344 1 8		
				14,994 1 8

II. Trust Funds.

1. Telford Fund:—				
Three per Cent. Consols . .	£2,839 10 6			
Three per Cent. Annuities .	2,570 5 1			
		5,409 15 7		
Unexpended Income, Three per Cent. Consols	2,377 10 6			
Ditto, Annuities.	476 8 5			
		2,853 18 11		
			8,263 14 6	
2. Manby Premium:—				
Great Eastern Railway Five per Cent. Preference Stock			200 0 0	
3. Miller Fund:—				
Lancashire and Yorkshire Railway Four per Cent. Debenture Stock .	£2,000 0 0			
Great Eastern ditto . .	1,100 0 0			
		3,100 0 0		
Unexpended Income, Three per Cent. Consols	582 18 6			
Ditto, Annuities	691 5 8			
		1,274 4 2		
			4,374 4 2	
4. Howard Bequest:—				
New Three per Cents.			551 14 6	
				13,389 13 2
Total Nominal or par Value Carried forward				£28,383 14 10

	£. s. d.	£. s. d.
Brought forward . . .		28,383 14 10
Cash in the hands of the Treasurer, Dec. 1, 1872	281 11 7	
Less Petty Cash due to the Secretary . .	10 16 6	
		270 15 1
Together amounting to . . .		£28,654 9 11

as compared with £25,373. 3*s.* 4*d.* at the date of the last Report.

The following is a Summary of the different Securities in which the above Funds are placed:—

	£. s. d.	£. s. d.
Government Stocks:—		
Three per Cent. Consols	5,799 19 6	
Three per Cent. Annuities	3,737 19 2	
New Three per Cents.	1,895 16 2	
		11,433 14 10
Great Eastern Railway:—		
Five per Cent. Preference Stock . . .	200 0 0	
Four per Cent. Debenture Stock . . .	4,750 0 0	
		4,950 0 0
Lancashire and Yorkshire Railway:—		
Four per Cent. Debenture Stock . . .	. .	2,000 0 0
London and North Western Railway:—		
Four per Cent. Debenture Stock . . .	. .	2,500 0 0
London, Brighton, and South Coast Railway:—		
Four per Cent. Debenture Stock . . .	. .	1,000 0 0
Four and a-Half per Cent. Debenture Stock .	. .	1,500 0 0
North Eastern Railway:—		
Four per Cent. Debenture Stock . . .	. .	3,000 0 0
Great Northern Railway:—		
Four per Cent. Debenture Stock . . .	. .	1,000 0 0
Manchester, Sheffield, and Lincolnshire Railway:—		
Four and a Half per Cent. Debenture Stock .	. .	1,000 0 0
Total Nominal or par Value . .		£28,383 14 10

The outstanding subscriptions at the close of the financial year, on the 30th November last, were:—

		£. s. d.	£. s. d.
For 1872.	From members of all classes residing abroad	58 5 6	
	Ditto, in the United Kingdom . .	155 18 6	
			214 4 0
For 1871.	From members of all classes residing in the United Kingdom		18 7 6
For 1870.	From Associate residing in the United Kingdom		3 3 0
	Total		£235 14 6

On the occasion of the Annual Dinner the Institution had the privilege and the honour of receiving, as guests, H.R.H. Prince

Arthur, the Prime Minister, and other Members of Her Majesty's Cabinet, besides several men of science and distinguished representatives of various professions. This recognition of the Engineers of the United Kingdom, and the graceful and appreciative sentences uttered by some of the visitors, may be regarded as highly complimentary to the Engineers of all countries.

In reference to the President's Conversazione, a successful departure from the previously established practice was made this year. Instead of the Conversazione being given in the rooms of the Institution, it was held, by permission of Her Majesty's Commissioners, in the West Galleries of the Annual International Exhibition at South Kensington. This portion of the building comprised the British Picture Gallery and the Machinery Court. The machinery, which was shown in motion, related to cotton, paper, stationery, and printing processes, and was kindly explained to the visitors by several members of the Institution, as well as by the different exhibitors. A few models and scientific inventions were removed from other parts of the Exhibition, and some were specially lent for the occasion; but the display was for the most part limited to the objects contained in the two galleries.

This Conversazione has been universally regarded as a most brilliant and successful reception. Ample space, abundance of light, and much to see and admire, with opportunities for doing both, were the features of the entertainment. Although, in this instance, the mechanical novelties hitherto contributed for exhibition were absent, it is possible that on some future occasion permission may be granted to supplement the exhibits of the year by the loan of special objects such as the Institution has been previously in the habit of obtaining. One other innovation has to be noticed—that ladies formed part of the company. For all these novelties, and for the extremely liberal and handsome manner in which the arrangements were carried out, the members are entirely indebted to the President and Mrs. Hawksley.

Although the Institution in its infancy might have been regarded simply as a private society, now, with a Royal Charter and undoubted influence, it must be looked upon as a public body. The aim, then, should be to seek to obtain a still higher status for its members, both individually and in their corporate capacity, and to show that it has the power and the authority to govern and regulate the profession, and that it is competent, under proper guidance, to attain a yet more important position.

[Abstract of Receipts and Expenditure.

ABSTRACT *of* RECEIPTS *and* EXPENDITURE

RECEIPTS.

Dr.	£.	s.	d.	£.	s.	d.
To Balance in the hands of the Treasurer				377	12	3
" " " Secretary				1	10	9
— Subscriptions and Fees:—						
Arrears	225	15	0			
Current	5,643	15	0			
Subscriptions for 1873	65	2	0			
" 1874 (in part)	1	1	0			
Fees	431	11	0			
Life Compositions	76	2	6			
				6,443	6	6
— Building Fund				700	12	6
— Publication Fund				85	18	6
— Council Fund				57	10	0
— Publications :—Sale of Transactions				114	13	4
— Telford Fund :—						
Dividends, 1 Year, on £2,839. 10*s.* 6*d.*, Three per Cent. Consols	83	7	11			
Ditto, 1 Year, on £2,570. 5*s.* 1*d.*, Three per Cent. Reduced	75	10	11			
Ditto, 1 Year, on £2,377. 10*s.* 6*d.*, Three per Cent. Consols (Unexpended Dividends) . .	69	17	0			
Ditto, 1 Year, on £476. 8*s.* 5*d.*, Three per Cent. Reduced (Unexpended Dividends). . . .	13	19	5			
				242	15	3
— Manby Premium :—						
Dividends, 1 Year, on £200, Great Eastern Railway, Co. Norfolk, Five per Cent. Preference Stock				9	15	5
— Miller Fund :—						
Dividends, 1 Year, on £2,000, Lancashire and Yorkshire Railway Four per Cent. Debenture Stock	78	3	4			
Ditto, 1 Year, on £1,100, Great Eastern Ditto .	43	0	0			
Ditto, 1 Year, on £582. 18*s.* 6*d.*, Three per Cent. Consols (Unexpended Dividends)	17	2	7			
Ditto, 1 Year, on £691. 5*s.* 8*d.*, Three per Cent. Reduced (Unexpended Dividends)	20	5	8			
				158	11	7
— Institution Investments:—						
Dividends, 1 Year, on £3,650, Great Eastern Railway Four per Cent. Debenture Stock. .	142	12	6			
Ditto, 6 Months, on £1,162, London and North Western Ditto	22	13	2			
Ditto, 6 Months, on £2,500, Ditto	48	19	2			
Ditto, 1 Year, on £1,000, London, Brighton, and South Coast Ditto	39	1	8			
Ditto, 6 Months, on £1,500, North Eastern Ditto	29	5	0			
Ditto, 6 Months, on £3,000, Ditto	58	15	0			
Ditto, 1 Year, on £1,000, Great Northern Ditto	39	1	8			
Ditto, 1 Year, on £1,500, London, Brighton, and South Coast Ditto, Four and a Half per Cent. Debenture Stock	65	19	1			
Ditto, 1 Year, on £1,000, Manchester, Sheffield, and Lincolnshire Ditto	43	19	4			
Carried forward . .	£490	6	7	£8,192	6	1

from the 1st DEC., 1871, *to the* 30th NOV., 1872.

PAYMENTS.

Cr.	£.	s.	d.	£.	s.	d.
By House, Great George Street, for Rent, &c.:—						
Repairs	137	1	8			
Rent	643	12	8			
Rates and Taxes	76	12	9			
Insurance	20	11	6			
Furniture	25	18	6			
				903	17	1
— Salaries				1,100	0	0
— Clerks, Messengers, and Housekeeper				384	0	0
— Donation to late Messenger and Housekeeper				54	16	6
— Postage and Parcels:—						
Postage	56	13	9			
Parcels	0	13	7			
				57	7	4
— Stationery, Engraving, Printing Cards, Circulars, &c.				473	4	1
— Light and Fuel:—						
Coals	46	13	0			
Candles	0	2	0			
Oil	0	10	4			
Gas	48	13	3			
				95	18	7
— Tea and Coffee				29	2	5
— Library:—						
Books	227	14	11			
Periodicals	21	10	6			
Binding Books	105	16	3			
Council Gift	17	5	0			
Maps	47	5	0			
				419	11	8
— Publication, Minutes of Proceedings				1,826	9	10
— Telford Premiums				155	2	9
— Watt Medal				2	7	6
— Manby Premium				18	5	3
— Miller Prizes				76	10	9
— Diplomas				37	19	3
— Manuscripts, Original Papers, and Drawings				0	11	10
— Annual Dinner (Official Invitations, &c.)				124	7	4
— Winding and Repairing Clocks				1	10	0
— Incidental Expenses:—						
Christmas Gifts	1	11	0			
Assistance at Ordinary Meetings	9	8	6			
Ditto at Students' Meetings	2	5	0			
Beating Carpets and Sweeping Chimneys	1	8	0			
Household Utensils, Repairs, and Expenses	98	4	8			
				112	17	2
— Legal Expenses				12	11	8
Carried forward				£5,586	11	0

ABSTRACT *of* RECEIPTS *and* EXPENDITURE

RECEIPTS—*cont.*

Dr.	£.	s.	d.	£.	s.	d.
Brought forward . .	490	6	7	8,192	6	1
To Institution Investments:—*cont.*						
Dividends, 1 Year, on £1,344. 1*s.* 8*d.*, New Three per Cents.	39	9	8			
Deposit Interest	10	11	5			
				540	7	8
— Donations to Library				10	5	0
— Sale of Duplicate Books				30	15	0
				£8,773	13	9
— Howard Bequest				500	0	0
— Balance of Petty Cash, Nov. 30, 1872, due to the Secretary				10	16	6
				£9,284	10	3

from the 1ST DEC., 1871, *to the* 30TH NOV., 1872.

PAYMENTS—*cont.*

Cr.	£.	s.	d.	£.	s.	d.
Brought forward				5,586	11	0
By Benevolent Fund Disbursements, 1872				7	8	11
— Howard Bequest :—						
£551 14*s.* 6*d.*, New Three per Cents.	500	0	0			
— Institution Investments :—						
£1,338, London and North Western Railway Company's Four per Cent. Debenture Stock	1,376	16	6			
£1,500, North Eastern Ditto, ditto . .	1,532	2	3			
				3,408	18	9
— Balance November 30, 1872, in the hands of the Treasurer . .				281	11	7
				£9,284	10	3

Examined and compared the above Account with the Vouchers and the Cash Book, and find it to be correct, leaving a Balance in the hands of the Treasurer of Two Hundred and Eighty-one Pounds, Eleven Shillings, and Sevenpence.—Nov. 30th, 1872.

(Signed) ROBT. C. MAY, J. WOLFE BARRY, } *Auditors.*
JAMES FORREST, *Secretary.*

December 6*th*, 1872.

[SUBJECTS FOR PAPERS.

SUBJECTS FOR PAPERS.

Session 1872–73.

The Council of The Institution of Civil Engineers invite communications dealing in a complete and comprehensive manner with any of the Subjects comprised in the following list, as well as upon others, such as—

a. Account of the Progress of any Work in Civil Engineering, as far as absolutely executed (Smeaton's Narrative of the Building of the Edystone Lighthouse may be taken as an example).

b. Descriptions of distinct classes of Engines and Machines of various kinds.

c. Practical Essays on Subjects allied to Engineering, as, for instance, Metallurgy; and

d. Particulars of Experiments and Observations connected with Engineering Science and Practice.

List.

1. On the Application of Graphic Methods in the Solution of Engineering Problems, and in the Reduction of Experimental Observations.
2. On the Elasticity, or Resistance to Deflection, of Masonry, Brickwork, and Concrete, with observations on the Deflection of the tops of Bridge Piers, by unequal loading of the Arches abutting on them.
3. On the Methods of Constructing the Foundations of some of the principal Bridges in Holland and in the United States.
4. On Bridges of large span, considered with reference to examples, now in progress or recently completed, in the United States; including an account of the testing, and of the effects produced by variations of temperature.
5. On the Theory and Practical Design of Retaining Walls for sustaining earth, or water, and on experimental tests of the accuracy of the various theories.
6. On the Different Systems of Road Traction Engines, with details of the results in each case.

7. On the Use of Concrete, or Béton, in large masses, for Harbour Works and for Monolithic Structures.
8. On Dredging Machinery, and on the cost of raising and depositing the material.
9. On the Appliances and Methods for Rock-boring and Blasting, in this country and abroad, and on the results obtained.
10. On the Gauge of Railways.
11. On the Systems of Fixed Signals on Railways, and on the connection between the signals and the points.
12. On Modern Locomotive Engines, designed with a view to economy, durability, and facility of repair, including particulars of the duty performed, of the cost of repairs, &c.
13. On the different Systems for Surmounting Inclines on Mountain Railways.
14. On the various Modes of Dealing with Sewage, either for its disposal or utilization.
15. On the Separate System of Sewering Towns, with a detailed description of the works in a town to which this system has been wholly or partially applied, and particulars as to the results.
16. On the Ventilation of Sewers, with a résumé of the Experiments as to the motion, pressure, &c., of Gas in the Sewers.
17. On the Constant Service of Water Supply, with special reference to its introduction into the metropolis, in substitution for the Intermittent System.
18. On Street Railways and Tramways through Cities and Towns, and on the best mode of working them.
19. On the Application of Steam as a Motive Power for Pumping Water or Sewage, with a comparison of the advantages of different classes of Engines, and details of the cost of working for long periods.
20. On the various descriptions of Pumps employed for Raising Water or Sewage, and their relative efficiency; and on the employment of Water as a Motive Power for pumping, by means of Water-Wheels, Turbines, Water Pressure Engines, or other Machines.
21. On the Employment of Steam Power in Agriculture.
22. On the Laws governing the Flow of Steam and other Gases through Orifices, Pipes, &c., and on Experiments to determine these Laws.
23. On the Methods of Transmitting Force to distant points.
24. On the best practical Use of Steam in Steam Engines, and on

the effects of the various modes of producing Condensation.

25. On the modern practice of Marine Engineering, having reference to Economy of Working Expenses, by Superheating, Surface Condensing, great Expansion, High Pressure, &c.
26. On the Present State of Science in regard to the Manufacture of Gas for the purposes of Illumination.
27. On the Construction of Sluices, for the expeditious filling and emptying of Locks of large size on navigable Canals.
28. On the Harbour and Dock Works at Spezzia.
29. On the Maintenance, by Sluicing, of the Harbours on the Coasts of France, Belgium, and Holland.
30. On the Practice and Results of Irrigation in Northern India.
31. On the Sea Works at the mouth of the Adour, and the effect produced by them on the bar of that river.
32. On the Sea Works at the mouth of the River Maas, and the effects produced thereby.
33. On the Manufacture of Iron and Steel as now pursued, the effect on strength and tenacity of the admixture of substances with the Ore, and any test, other than fracture, by which the quality may be ascertained.
34. On the various Methods of Draining distant isolated sections of Mines.
35. On Compressed Air as a Motive Power for Machinery in Mines, with some account of its application on the Continent.
36. On the Use of the Diving Apparatus in Mines, especially in Westphalia and in Germany.
37. On the Systems and Apparatus at present used in Telegraphy.

For approved Original Communications, the Council will be prepared to award the Premiums arising out of special Funds devoted for the purpose. They will not, however, consider themselves bound to make any award should there not be any communication of adequate merit; but, on the other hand, more than one Premium will be given, if there are several deserving memoirs on the same subject. It is to be understood that, in this matter, no distinction will be made between essays received from a Member or an Associate of the Institution, or from any other person, whether a Native or a Foreigner.

The Communications should be written in the impersonal pronoun, and be legibly transcribed on foolscap paper, on the one side only, leaving a sufficient margin on the left side, in order that the sheets may be bound. A concise abstract must accompany every Paper.

The Drawings should be on mounted paper, and with as many details as may be necessary to illustrate the subject. Enlarged Diagrams, to such a scale that they may be clearly visible when suspended in the Theatre of the Institution, should be sent for the illustration of particular portions.

Papers which have been read at the Meetings of other Societies, or have been published in any form, cannot be read at a Meeting of the Institution, nor be admitted to competition for the Premiums.

The Communications must be forwarded, on or before the 31st of December, 1872, to the house of the Institution, No. 25, Great George Street, Westminster, S.W., where any further information may be obtained.

Charles Manby, *Honorary Secretary.*
James Forrest, *Secretary.*

The Institution of Civil Engineers,
25, *Great George Street, Westminster, S.W.*,
31*st August*, 1872.

Excerpt Bye-Laws, Section XV., Clause 3.

"Every Paper, Map, Plan, Drawing, or Model presented to the Institution shall be considered the property thereof, unless there shall have been some previous arrangement to the contrary, and the Council may publish the same, in any way and at any time they may think proper. But should the Council refuse, or delay the publication of such Paper beyond a reasonable time, the Author thereof shall have a right to copy the same, and to publish it as he may think fit, having previously given notice, in writing, to the Secretary of his intention. No person shall publish, or give his consent for the publication of any communication presented and belonging to the Institution, without the previous consent of the Council."

Notice.

It has frequently occurred that, in Papers which have been considered deserving of being read and published, and have even had Premiums awarded to them, the Authors may have advanced somewhat doubtful theories, or may have arrived at conclusions at variance with received opinions. The Council would, therefore, emphatically repeat, that the Institution must not, as a body, be considered responsible for the facts and opinions advanced in the Papers or in the consequent Discussions; and it must be understood, that such Papers may have Medals and Premiums awarded to them, on account of the Science, Talent, or Industry displayed in the consideration of the subject, and for the good which may be expected to result from the discussion and the inquiry; but that such notice, or award, must not be considered as any expression of opinion, on the part of the Institution, of the correctness of any of the views entertained by the Authors of the Papers.

ORIGINAL COMMUNICATIONS

RECEIVED BETWEEN DECEMBER 1st, 1871, AND NOVEMBER 30th, 1872.

AUTHORS.

Abel, F. A. No. 1,342.—Explosive Agents applied to Industrial Purposes.

Bainbridge, E. No. 1,327.—On the Kind-Chaudron System of Sinking Shafts through Water-bearing Strata, without the use of Pumping Machinery.

Bell, I. L. No. 1,328.—On the conditions which favour, and those which limit, the Economy of Fuel in the Blast Furnace for Smelting Iron.

Bow, R. H. No. 1,329.—Improvements in the erection of certain Arched Structures.

Britten, B. No. 1,336.—On the Construction of Heavy Artillery, with reference to economy of the mechanical forces engaged.

Browne, Major J., R.E. No. 1,319.—On the tracing and construction of Roads in Mountainous Tropical Countries.

Dowson, J. E. No. 1,324.—Street Railways.

Fox, C. D., and Fox, F. No. 1,332.—On the Pennsylvania Railroad; with observations on some peculiarities of American Railway Construction and Management.

Gainsford, T. R. No. 1,337.—Remarks as to the Arrangement of Passenger Stations for Through Lines at towns and junctions of importance.

Gordon, G. No. 1,318.—On the Value of Water and its Storage and Distribution in Southern India.

Harding, J. No. 1,333.—On the Chañaral Railway.

Higginson, H. P. No. 1,315.—Description of the Pennair Anicut Cuddapah Collectorate.

Knowles, Sir F. C. No. 1,331.—On a method of Mechanical Puddling of Iron by the union of Chemical and Mechanical Action.

—— No. 1,314.—On the Motions of Translation and Rotation of an Oblong Shot.

Langley, A. A., and Bellamy, C. J. No. 1,334.—Quarrying in the Festiniog District, North Wales.

Latham, J. H. No. 1,325.—Description of the Soonkêsala Canal of the Madras Irrigation and Canal Company.

AUTHORS.

Lawford, A. C. No. 1,317.—On the River Defences employed in Southern India, particularly on its principal river the Cauvery.

Leslie, B. No. 1,322.—Account of the Bridge over the Gorai River on the Goalundo Extension of the Eastern Bengal Railway.

Macassey, L. No. 1,323.—Description of the new Floating and Tidal Docks at Belfast.

Murray, W. No. 1,330.—Description of the Railway from the Tharsis Mines to the River Odiel, and of the Loading Pier erected there.

Paddon, J. B. No. 1,341.—Description of Gas Works constructed for the Brighton and Hove General Gas Company, Portslade, Sussex.

Sargeant, Lieut., R.A. No. 1,321.—On Chorography, or Globose Development.

Sopwith, T., Jun. No. 1,340. The Mont Cenis Tunnel.

Vernon-Harcourt, L. F. No. 1,316.—Description of the New South Dock in the Isle of Dogs, forming part of the West India Docks.

Vidler, M. No. 1,320.—On Shingle Beach and Artificial Coast Defence as used on the South Coast of England.

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January 14, 1873.
T. HAWKSLEY, President,
in the Chair.

At the commencement of the proceedings, Mr. Hawksley, President, thus addressed the Meeting:—

Gentlemen,

I have a sorrowful duty to perform—I have it in command from the Council to announce to you that death has removed from the roll of this Institution the most distinguished name of His Majesty the Emperor Napoleon III.—I am to ask you to express by your solemn silence your heartfelt sympathy and profound condolence with Her Majesty the Empress, the Prince Imperial, and the other members of the Imperial Family; and that this expression of your feeling be communicated to Her Majesty the Empress from the Council in the usual manner.

The following Candidates were balloted for and duly elected:—Arrott Browning and Baron Max-Maria von Weber, as Members; William Frederick Alphonse Archibald, Stud. Inst. C.E., Nicholas Procter Burgh, Henry Carmichael Christopher, Edmund Henry Harris, Benjamin Kitt, John Mackay, Joseph Prime Maxwell, Stud. Inst. C.E., William Henry Scott, John Isaac Thornycroft, and Richard Tiplady, as Associates.

It was announced that the following Candidates, having been duly recommended, had been admitted by the Council, under the provisions of Sect. IV. of the Bye-Laws, as Students of the Institution:—James Samuel Brown, William Coulthurst Gibbons, Arthur Trethowan Goodfellow, Alfred Joyce, Horace Chaloner Knox, Theophilus Michell, Alexander Millar, jun., George Moyle, George Augustus Grant Shawe, and Zacchæus Walker.

No. 1,350.—"On the Practice and Results of Irrigation in Northern India." By Colonel W. H. Greathed, C.B., R.E., Chief Engineer of Irrigation to the Government of the North-Western Provinces.[1]

As the construction and application of works of Irrigation in India have opened a large field for hydraulic engineering, which will extend from year to year, it has been thought that a brief account of what has been done, and of what is now doing, in that portion of Upper India in which artificial irrigation has been practised for the longest period, and on the largest scale, will interest the Members of the Institution of Civil Engineers, and others concerned in the welfare and advancement of our Indian possessions.

A passing reference will be made to various large undertakings in other provinces of India; but the Paper will be principally confined to a description of the works which have been and are now being constructed under the Government of the North-Western Provinces.

In the first instance, attention will be directed to the tract of Hindostan lying south of the great Himalayan range, and included between the river Bhrahmaputra on the east, and the rivers which merge into the Indus on the west side. The principal geographical features of this region are the plain drained by the Ganges and its tributaries flowing south-east; the plain traversed by the Indus and its tributaries flowing south-west; and the intervening water-shed, which, disregarding minor variations of character, may be generally spoken of as the table-land of Central India. The length of the line along the foot of the Himalaya to the North of Hindostan is 1,500 miles; the distance from north to south measures 26° of latitude, and the country is four times as large as France in area and in population. The plains of the Ganges and of the Indus rise gradually, from the level of the sea at the mouths of the great rivers, to about 1,000 ft. and 1,100 ft. at the points where the Jumna and the Indus respectively leave the mountains.[2] The highest level of the central table-land is about 2,000 ft. above the level of the sea, and it stands nearly 600 ft.[3] above the plain of the

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[1] The discussion upon this Paper extended over portions of two evenings, but an abstract of the whole is given consecutively.

[2] Attock, 1,100 ft., G. T. S. Jumna debouche 1,000 ft., Strachey.

[3] Height of plain at Allahabad . . . 400 ft. above sea-level.
Height of table-land opposite Allahabad 1,000 ,, ,, ,,

Ganges, which runs between its north-eastern face and the Himalaya.[1]

The intense heat of the southern border of the continent of Asia, when subjected to the maximum power of the sun's rays as it attains its northern declination, creates a current at the earth's surface from the south during the summer, which, blowing over a large expanse of ocean within the tropics, becomes highly charged with vapour; while in the winter the rapid cooling of the land as the sun passes south of the equator, causes a corresponding current from the north to the hotter southern latitudes. From causes, which for present purposes it is not necessary to investigate, these currents respectively become south-westerly and north-easterly winds in the Indian seas north of the equator. The term 'south-west monsoon' is generally used to express the season from the beginning of May to the end of October, during which the winds for the most part blow from that direction; and the term 'north-east monsoon' is applied to the autumn and winter half of the year.

Very near the west coast, the table-land of Central India rises to a height of from 2,000 ft. to 5,000 ft. above the sea, and terminates abruptly in a scarped face, called the Western Ghāts. During the south-west monsoon a great rainfall takes place upon these hills, which are generally higher than the adjoining table-land; and though their summits are not continuous, only a small portion of rain penetrates and falls upon their eastern side. As far, therefore, as the break in the line of Ghāts, which is made by the mouths of the Nerbudda and the Taptee, the summer rainfall on the coast line continues great, and the fall on the table-land is scanty. The area so affected includes the greater part of the Madras Presidency, the plain of Mysore, and some part of the Nizam's dominions.

It would seem that the rain-clouds ascend the valleys of the Nerbudda and the Taptee and break on the high land which borders them; in consequence, the country called the 'Central Provinces' has more rain than the table-land which is shut in by the Western Ghāts. Traveling up the west coast of India, the rainfall rapidly decreases both on the coast and in the interior, until at the mouths of the Indus there is practically none at all. And over all this region the south-west wind still blows as freely as in the regions further south. The rainfall on the eastern side of

[1] In compiling this Paper advantage has been taken of a map prepared by General Strachey and Dr. Brandis, for the recent meeting of the British Association, showing the average rainfall over the surface of British India.—W. H. G.

the peninsula during the south-west monsoon is estimated to be as follows:—

	Inches.		Inches.
Palamcottah	10	Vizagapatam	39
Trichinopoly	20	Cuttack	47
Madras	39	Calcutta	56
Masulipatam	29		

At the southern point of India, and in Ceylon, the south-west monsoon brings but little rain. The amount, however, increases up the eastern coast of the peninsula; and on the east of the Bay of Bengal there is a rainfall equal to that on the Western Ghāts, extending over the country between the sea and the Himalaya, which, at the head of the bay, are not very far apart.

Thence, in the plains of the Ganges, the rain constantly diminishes as the distance from the sea increases, and likewise as the distance from the Himalaya increases, until to the westward, the rainfall, even at the foot of the Himalaya, is greatly attenuated. General Strachey and Dr. Brandis have grouped the surface of Hindostan into the arid zone, in which the annual fall of rain is less than 15 inches; the dry zone, in which the rain does not exceed 30 inches; and the wet zone, which has a rainfall everywhere of not less than 75 inches.

The agricultural conditions in the several parts of India are influenced by these varying degrees of moisture as well as those of soil and of temperature. The temperature ranges from tropical in the south, with an approximately uniform heat, to semi-temperate in the north, where the summer and winter are sharply defined. The change in the two seasons becomes greater as the latitude increases.

The Madras Presidency is traversed by great rivers, the Kistnah, Godavery, Cauvery, Coleroon, Pennair, and others, falling into the Bay of Bengal. These rivers rise in the Ghāts, and consequently carry during the south-west monsoon great volumes of water, whilst the region through which they flow is generally dry. The table-lands, when unirrigated, produce nothing but the lowest class of cereals, which the rainfall generally suffices to bring to maturity. But a large amount of irrigation is effected from tanks, which husband the south-west rainfall in sufficient quantities for the cultivation of rice; and it appears that, under the even temperature of the tropics, rice can be cultivated irrespective of season so long as the water lasts. As a rule, irrigated land is sown with rice, and by the time that crop is matured there is no water left for other purposes; so that even the irrigated lands bear but one crop a year. Recourse cannot be had to wells for the purpose of irrigation, because of the depth of the water from the surface of the land, and hence a large extent lies waste, and is in effect an unproductive 'bush.'

It is probably owing to the broken character of the surface of the country, which is scarred by the outcrop of rocks, that advantage cannot be taken of the waters flowing in the great rivers to irrigate the uplands. As it is, throughout the Madras Presidency, canal irrigation is confined to the deltas formed at the mouths of the great rivers. No large channels are necessary therefore for the distribution of water, nor are bridges of communication requisite, because carts are not employed in the delta country; moreover, there is no considerable velocity of current to injure the banks of canals. All of these circumstances tend to cheapen construction and maintenance. The areas irrigated in the deltas of the Madras Presidency are as follows:—

District.	Acres irrigated.
Godavery	225,032
Kistnah	144,591
Tanjore	698,142
Nellore	176,927
Total acres .	1,244,692

Moreover the practice of agriculture brings nearly the whole cultivated area under crop at one time, when the rivers are at their height. It is, therefore, only necessary to raise the flood-waters slightly by weirs to create the means of irrigation, which cease when the monsoon passes off, and they are no longer required. But whilst water is obtainable it is very abundant, and, in consequence, the irrigation is conducted under favourable circumstances. The total area classed by the revenue authorities as irrigated amounts to 3,300,017 acres, nearly one-fourth of the cultivated area. After deducting the area supplied by canals, there remains a residue of upwards of 2,000,000 acres, principally irrigated from tanks.

In the Nizam's territory and Central India the conditions of soil are much the same as in Madras east of the Ghāts, but tanks are not so frequent. In the shallow and argillaceous soils the rainfall of 30 inches or 40 inches brings on crops of millet; whilst the black cotton soils, composed generally of decomposed trap, having a great faculty of retaining moisture, produce the cotton crops of the Berārs, with the aid of 43 inches of rain.

In Lower Bengal the terrible famine of 1866 led to the construction of a large system of canals in Orissa, apparently, not yet much used. A second scarcity will teach their value, even if the people do not sooner learn that high farming by means of abundant water leads to profitable increase of crops in ordinary years.

The rest of Lower Bengal has no State irrigation, and probably it has no great need of it. The greater part of the country is deltaic, the rainfall is considerable—being from 65 inches to 75 inches—the population large, and water so near the surface generally, that it can be raised by simple native mechanical appliances. In Eastern Bengal the natural rainfall suffices for all requirements.

North of the Lower Ganges, which traverses Bengal diagonally from N.W. to S.E., the country is profusely watered by about 150 inches of rain, and by numerous great rivers which drain into the Bay of Bengal. Fibres, such as jute and hemp, rice and oilseeds, are produced in great abundance in these regions, and they furnish the chief exports of the Calcutta market.

Higher up the Ganges is the rich province of Behār, which enjoys, what for India is considered, a temperate climate. It has a good loamy soil, and a liberal rainfall. Indigo is extensively cultivated; wheat, barley and oats are successfully raised. The country is verdant throughout the year, and large quantities of cattle, sheep, and horses are reared on the excellent natural grasses. This description applies principally to the districts on the left bank of the Ganges, which obtain more rain than those on the right. Canals are, accordingly, being made from the Soane river, designed to develop the cultivation of sugar, rice, indigo, and cotton. Other canals from the river Gunduck are under consideration, which would secure indigo against all risk, and greatly increase sugar cultivation, now effected to a limited extent with well-water.

In the Benares division of the North-Western Provinces, the northern districts are liberally moistened as in Behār, whilst those more remote from the Himalaya have only a slight advantage in rainfall over the average of the North-Western Provinces proper. There are no existing State works of irrigation in the Benares division; but a scheme is contemplated for irrigating the southern districts from a great series of distributaries taken from the river Sardah, in the province of Oude.

North-Western Provinces.

In the North-Western Provinces (Plate 6)—exclusively of the Benares division—irrigation may be described as consisting of three zones:—

1st. The Sub-Himalayan Tract, north of the river Rāmgunga, which is generally copiously watered by the rainfall on the mountains, and by numerous small rivers flowing southwards out of them. Most of these small rivers dry up soon after the termination of the rainy season, but on a great part of the length of this tract a deposit of sand and boulders, forming a continuous belt about 15 miles wide, creates a vast filter-bed which, being fortunately bordered on the down-hill side by a band of clay of considerable width, becomes a covered reservoir. The natural pressure, augmented by the rapid slope across which the filter-bed lies, appears to force water under the clay, and produces a line of springs, on the other side of the clay band, which, feeding numerous small streams, refresh the country. The local name of the belt of boulder is 'Bhābur,' and the name of the tract which it waters by filtration is 'Terai.' The drainage runs southwards to the Rāmgunga and Ganges.

2nd. The 'Plains,' being the area included between the Rāmgunga and the Jumna rivers, and including the Muttra and Agra districts on the right of the Jumna. This great tract has a loamy upper soil, varying from sand in some parts, to light clay in others. But fine sand is generally found at no great depth throughout this formation. The drainage runs from N.W. to S.E., parallel to the main rivers, the Ganges and the Jumna, which embrace nearly the whole area.

3rd. The province of Bundelcund, which slopes from the high tablelands of Central India northwards towards the Jumna. The lands bordering the rivers are dry and stony, and higher than the intervening basins, which consist generally of rich black cotton soil. There has been a great upheaval of the region near the foot of the table-land; and trap and granite rocks crop out freely, forming isolated hills of fantastic shapes.

The climate of the North-Western Provinces is exceedingly dry, and hot westerly winds prevail, during the months of April, May, and June, over its whole surface, excepting the Sub-Himalayan zone. During that season vegetation of unwatered plants is apparently suspended, except in the case of the melon tribe, which thrives on the dry sandy beds of rivers, hot enough to blister the feet. The rain-clouds of the south-west monsoon seem to travel up the valley of the Ganges, and reach the North-Western Provinces about a fortnight after rain has commenced in Calcutta. Marvellous is the sight and delicious the sensation when the rain sets in. Nature, which seemed dead for three months past, bursts suddenly into life; it is a sober statement and no traveller's tale, that plains at evening brown with the dust which has been their habitual covering for months past, acquire a distinct green tinge by the morning which succeeds the first night's blessed fall of rain.

After the first twelve hours of down-pour, every plough in the country is upon the lands, and the season of agriculture has commenced.

Without saturation, the 'pan' of indurated soil which underlies the dust cannot be broken by the wooden ploughs and puny cattle which are in use. If the commencement of the rains is long deferred, the operations of agriculture are retarded, and all its economy disordered: if there is no rain, the land is not broken and seed is not sown: if the fall of rain is not distributed over a sufficient number of days, or if it is not sufficiently gradual and protracted, the crop withers; and if the rains abruptly cease, it fails.

These uncertain crops of the rainy season are Indian corn and millet of various kinds—the lowest type of cereals—and they form the staple food of the agricultural labouring classes. Such grains are not sold in abundance; each small proprietor or tenant sowing only sufficient to support his family through the year, if the crop is fair. If the crop fails wholly or in part, he cannot supplement his store by purchase in the market at harvest time; for he has no means, and his neighbours are stinted like himself. He must then have recourse to the 'bunya,' or village corn dealer and banker, who, on a mortgage of the holding, supplies food and bare necessaries, which he alone of the villagers has means of obtaining from distant markets. On a mortgage of the coming crop he advances seed for sowing, and when he gets a further lien upon the man's little farming implements and his surviving bullock, doles out money for the purchase of a yoke fellow, to replace the beast that died of starvation. Thenceforward the ryot is the bunya's serf; he is eaten up by compound interest at 2 per cent. a month, but it must be admitted he is contented, and regards his state of serfdom as a beneficent arrangement made by Providence to save him trouble.

This is the history of a peasant cultivator in seasons of scarcity; and, as is known from the experience of 1868–69, two seasons of scarcity make a famine. What a famine is in that country will be presently seen.

But suppose the ryot prosperous: the rains begun seasonably, say about the 20th of June; the light ploughing of the ground which is sufficient for his purpose is completed, and Indian corn dibbled in ridges on his field by the 1st of July. By the end of September the stems of Indian corn, which generally grow to a height of about eight feet, are cut and garnered, and the land is at once prepared for spring crops.

The various sorts of millet, largely sown as rain crops, are reaped by the end of October. It is usual to sow with them peas of various kinds, which occupy the land till February or March. Cotton is often sown on unirrigated lands in the rainy season, and a considerable quantity of a somewhat short staple is produced. The problem is to get the crop ripened before the November frosts nip off the seed-pods, a contingency to which backward crops are always liable.

The agricultural year in Northern India is sharply divided into a cold and a hot season; the former produces the ordinary crops of temperate climates, while the latter, with abundant water, matures sugar, indigo, rice, and other tropical products.

About the end of September the rains break up, and profiting by the last fall, the land destined for the spring harvest is ploughed, and sown with wheat, or barley, or 'gram,' an excellent large pulse which is the staple food for horses. In unirrigated districts, the latter is the only certain winter crop. Gram requires less moisture than wheat or barley; its foliage is retentive of dew, and as the plants are sheltered by the clods which are left on the gram fields, moisture is not quickly evaporated by the sun.

Fodder crops for cattle are not cultivated. There is not such a thing as a cultivated meadow in the country. No clover, no lucerne, no saintfoin, no roots, no rye-grass. The generality of indigenous grasses run very rank in the rainy season, and, when dry, possess scarcely any nourishment; but there is an extremely nutritious creeping grass, which grows plentifully wherever it can find moisture. On this grass cattle graze on the roadsides, on the fallows, on the margins of water-courses, and about the wells; and when it fails the luckiest of them have chopped wheat straw and the dry stems of the millet plant, which do not look very nutritious. The milch-cows get as much cotton seed as the cleaning of their owner's cotton may afford, and when given it is in its crude condition as it comes from the cleaning gin. He does not purchase any for their use. The consequence is that the cattle as a rule are poor and weak. At the end of the rains, though the grass is somewhat deteriorated in nutritious quality, they are, however, in tolerably good condition. But by the spring they are generally thin and miserable, and it is a matter of surprise how the cows produce even the five quarts or six quarts of milk a day, which may be taken as their average yield. When scarcity occurs, the only remedy practised is to drive the cattle from distant parts of the country to feed in the forest lands, at the foot of the Himalya. The sufferings and losses of the cattle from this treatment may well be understood. It is not to be expected that Hindoos, who form the great proportion of the agricultural communities, should do violence to their faith by fattening cattle for food; but a vast loss is incurred annually by the poorness of dairy-cows, and working-bullocks; and it is remarkable that though a Hindoo is greatly offended if any cow or beast is slaughtered, he has no compassion for them during their life, and will see them die of starvation, without compunction, if the loss does not fall upon himself.

The rainfall in Hindostan of the winter or north-east monsoon is everywhere less than in the summer. It is most on the eastern coast from Madras downwards. In Ceylon it is very copious, probably because the north-easterly air currents pass over a wide expanse of sea before reaching the island. On the west coast the only considerable winter rain is between Cananore and Vingorla, a space of about one-third the entire length of the Ghāts.

The rainfall of the north-east monsoon, like that of the south-west monsoon, diminishes in the valley of the Ganges as the distance increases from the sea, and becomes very light in the North-Western Provinces and the Punjâb, where it is due at Christmas. If the winter rain is favorable, the barley and wheat have a fair chance; but on unirrigated lands the spring crops of cereals are at the best very feeble and always uncertain. In the Bundelcund zone, on account of the exceeding dryness, barley and wheat are scarcely ever sown.

The spring harvest is finished near Allahabad by the beginning of April; and at the northern part of the provinces a month later. The land then rests until the rains begin. The atmosphere being charged with hot dust, and the fields brown, and case-hardened, under the burning sun of the second quarter of the year.

The 'Plains,' have an average annual rainfall of 26·6 inches, which would seem enough for agricultural needs. But the greater part of it falls, perhaps, in a fortnight, and there is no rain from September to July, except the Christmas showers. Consequently the ordinary food crops of the country often fail, and the richer crops, which bring it wealth, are entirely dependent on artificial irrigation, whether from wells or from canals.

In the Sub-Himalayan zone, which has a rainfall of 48·7 inches, rice is successfully produced, without artificial irrigation, in about two years out of three; and sugar is even less certain under the same condition.

In the Bundelcund zone the average rainfall—33·7 inches per annum—is sufficient when it comes in due time for the growth of ordinary monsoon crops; but it is especially fickle, and scarcity is in consequence very common in that country.

It needed not therefore the pressure of recurring famines to stimulate the people of the North-West to raise their agriculture to a higher level. Accordingly the practice of sinking wells for irrigation has prevailed from the earliest periods. The depth at which water is found below the surface in the zone of the 'Plains' varies from 10 ft. to 50 ft. At the lesser depth a little pit can be cheaply dug, which supplies as much water as can be lifted in a day in a jar attached to a light balance-beam worked by men. This process requires at least two men daily to keep a plot of an acre watered, a demand on labour which makes its employment on a large scale impossible.

Pits or wells of this description fall in during the rainy season, and must be renewed annually at the cost of the tenant. Deeper wells are generally lined with brushwood cylinders, and worked by bullock power. They cost from £5 to £18 each, according to depth and soil, and employ 6 men and 3 pairs of bullocks every day to keep 5 acres watered. The cost of the bullocks should not be wholly charged against the well, as they must be maintained for ploughing; but the working is necessarily a considerable expense.

The duration of such wells is as various as the character of the soils in which they are sunk; the shortest period which they last may, however, be taken as about 2 years, and the longest about 10 years. In some favoured tracts deep wells can be constructed without any lining; but this is exceptional to the general rule. A serious objection to the majority of wells is that they contain surface water only, and do not touch the springs; consequently the supply shrinks during the day; and if they are overdrawn, they fall in. As a rule, the springs can only be reached by wells lined with brickwork, costing from £15 to £30 each, a cost almost prohibitory to their employment for irrigation. They pay best—if water be plentiful—when made of sufficiently large diameter to allow 3 or 4 pairs of bullocks to work at once; in which case they command 20 acres of land, and cost from £80 to £100 each, a price which few occupiers can afford to give.

One or more brick-lined wells to supply water for drinking purposes are always found in every village; but no water can be spared from these wells for irrigation.

The general description of tenure in the North-Western Provinces is, that villages are held in co-parcenary by several proprietors, who pay an annual rent—estimated at half the proceeds from the land—to the Government, which is the landlord. The greater part of the lands are sublet to cottiers, of whom some have rights of occupancy in perpetuity—subject to payment of rent—and some are tenants at will. The former class pay rents which can only be enhanced on fixed and definite rules; the latter make their own arrangements.

It is difficult to conceive a system so fatal to large improvement of individual estates. The head tenants are hampered by their peasants who have right of occupancy, but who have not generally the means to do much themselves. And the Government obviously cannot undertake the improvement of individual farms. A wise measure is adopted by the State in giving advances to permanent occupiers for the construction of wells after the manner of our land improvement companies; but perhaps from a knowledge, on the part of the permanent occupier, that it is the interest of the head tenant to bring him in arrears, in order to obtain full possession of the land, advantage is not very largely taken of this faculty.

In the Sub-Himalayan zone wells have not been used, to any large extent, for irrigation. It has been the practice of the people, instead, to dam the numerous rivers which traverse the country from north to south; and to lead off, from above the dams, channels for the irrigation of the fields. Thus, to this day, considerable areas of rice and a certain area of sugar are cultivated in that region, but at a terrible price, though the money cost is small. The rapid slope of the country limits the effect of a single dam to a very small area, consequently the rivers are covered with dams; the result being a stoppage of outfall which has water-logged the land, and, under the influence of a tropical sun, converted into hot-beds of malaria the rank vegetation growing in these artificial morasses. A Bill is now before the legislative council of India giving powers to the administration to remove the whole of these dams, the Government making proper compensation, either in water supply from other sources or in money; and it is to be hoped that these beautiful districts may shortly be restored to a healthy condition.

In the third, or Bundelcund zone, no wells can be sunk for purposes of irrigation, because of the depth of the water from the surface, the poverty of the community, and the scanty population; circumstances which necessarily act upon each other. There are some considerable lakes, but their irrigation up to the present time has not exceeded 1,300 acres per annum. Hence that unfortunate country receives no fertilizing influence of water beyond the dews, and the capricious though often sufficient rainfall of the monsoon. In a great part of the tract, where the soil is unsuited to gram and other pulses, even winter crops cannot be grown.

It must not be supposed, from this account of the agricultural conditions of the North-Western Provinces, that the people are generally idle and apathetic. It is true that they are ignorant of the advantage of maintaining their cattle in good condition, and that they exhaust their lands by giving no manure excepting to sugar-cane crops; but many of the agricultural classes of the plains are skilful and laborious in preparing their land to the best advantage, with such means as are within their reach, and according to the knowledge they possess. Nor do they become dissatisfied with irrigation from wells for some time after canal irrigation comes in their way; they are attached to a practice which has endured throughout the East from the days of Nineveh; the really severe work of landing, and emptying the full skin-bags of water at the wells, is combined with a proportion of sitting, talking, and smoking, which suits their habits; and they will readily work on by watches night and day, if drought creates an unusual demand to which their wells can respond. Whilst they freely irrigate finer crops, the farmers will not as yet willingly pay for canal water to strengthen and insure their coarse-grain crops. If the rainfall fails, they hold off as long as possible, and only at the last moment will they try to obtain water to save them. This was the case in 1868–69, when 80,000 more acres of such cultivation were watered than in the preceding year.

Although individually diligent, after their manner, in their own concerns, the natives of Northern India are wanting both in the means, and in the mutual confidence, requisite for combinations of considerable numbers in any works of general advantage; and so it happens, generally, that unless improvements are proposed and carried through by the officers of the Government, they are not done at all. In fact, the people do not want to be improved, as is frequently found to be the case nearer home. There is no power of initiative in such matters amongst the agricultural community, whose poverty is shown, by the fact that only 15,174 persons out of the agricultural population of the North-Western Provinces,[1] amounting to $17\frac{1}{2}$ millions,[2] or less than one person in a thousand, paid income-tax in the year 1870–71, when all incomes below £50 per annum were assessed.

The people of the Bundelcund zone are an exception to the rule of diligence. Their picturesque country was once clothed with forests, and we know that, in former times, it produced sugar, from the evidence of stone sugar-presses which may be found in almost every village. The rainfall must then have been more abundant, and more constant than it is now, for there are no traces or traditions of old works of irrigation. It is probable that a wholesale destruction of timber effected the change of climate, which has brought the country to its present condition. The people are so impoverished as to be without energy or hope. If they sow a crop, it is said, that after scratching the ground just sufficiently for the purpose, they leave it alone till harvest time, when they go and see if anything has come up. This province, it may well be understood, is a great anxiety to the Government: its inhabitants are quiet and well disposed, but it is difficult to improve them, as a large proportion are subject to little independent chiefs, whose knowledge and enlightenment are not sufficient to enable them to appreciate improvements.

It has been necessary to dwell at some length upon the circumstances which enfold the technical matter under review, because, as the Government of India has embarked on a large expenditure in works of irrigation, which have been freely criticised in England, and even in newspapers in India, published at a distance from the countries concerned, it is proper that the necessity of such works should be proved. If this be not proved by the foregoing description of the conditions of the country, the following account of the liability of the North-Western Provinces to famine, and of the effect of canal irrigation in time of scarcity, may suffice to ensure conviction.

It has already been shown that canal irrigation is very beneficial to the North-Western Provinces, because no other can be relied on, and because the valuable staples of the country cannot be produced

[1] Report of Administration of the Income Tax in North-Western Provinces, 1870–71.

[2] Report of Census of North-Western Provinces, 1865, p. 86.

without irrigation. The Author will now adduce evidence to show the extent to which the country suffers from periodical famines where there are no canals, and how the construction of canals would render famine impossible. The evidence is extracted from the official narrative of the drought and famine of 1868–69, prepared for the information of the Secretary of State, in the Revenue Department of the Government—which has no connection with the management and control of irrigation works—and is as follows[1]:—

"Passing by seasons in which mere drought and scarcity have prevailed, the North-Western Provinces of India have been visited by three great famines during the current century, and they have, doubtless, been subject, from time immemorial, to like calamities, of which no complete record remains."

"In 1803, hail-storms, followed by a scanty monsoon, and a failure of the cold weather rains, sufficed to plunge the most opulent districts of the Lower Doab, and of Rohilkund, into bitter distress, and to entail upon the State a loss of revenue estimated at £300,000. Again, in 1837–38, five successive bad years culminated in a famine, which laid waste the greater part of the Doab and Rohilkund, cost the state a million sterling of revenue, and the people not less than 800,000 lives. The last famine occurred in 1860–61. It was the result of an almost entire failure of the monsoon in a country impoverished by the disasters of 1857. Its severity may be gathered from the fact, that nearly 10 millions of people, in the aggregate, received alms from the Government, while 7½ millions were employed on relief works; and the charges and losses incurred by the State amounted to £206,085."

"The outlay of Government on account of the scarcity of 1868–69 amounts to £317,285; and that the loss of life, which will presently be described, was not greatly exceeded, is due, under Providence, to the energy and skill with which the considerable means at their disposal were turned to account by the Government of the North-Western Provinces."

"There are two main reasons for this liability to famine; the first is, that the periodical rains, upon which the greater part of the crops depend, occasionally fail in quantity, or are distributed unequally over the seasons. The second principal reason is, the largeness of the numbers of people who are liable to be thrown out of employ as the pressure of high prices is enhanced."

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[1] Henvey's Narrative of the Drought and Famine in the North-Western Provinces, 1868–70, p. 1.

"The industrial and labouring classes, living by daily wages in the North-Western Provinces, numbered $7\frac{1}{2}$ millions in 1865."[1]

"These classes, in times of plenty, live chiefly upon the coarser grains, which may then be purchased at as little as 80 lbs. for a rupee."

"In times of scarcity (as we have shown above), the coarser grains are not to be procured, and the tendency of famines is to bring the prices of all grain, whether coarse or fine, to a common high level. Nor is this all: when prices rise to famine height, the employers of labour contract their expenditure, and discharge their workpeople. Not only is bread dear, but there is no money to buy grain, which has risen to 16 lbs. for a rupee."

The effects of the famine of 1868–69 in the district of Jhansi, in the Bundelcund zone, are described in the following extracts, from reports of the Commissioner of Jhansi:—

"The grain-dealers, in the hopes of still larger profits, withheld their stores from market. Seeing no prospect of a harvest from which to recover their loans, they stopped advances, whether of cash or grain, to their cultivating constituents, and left them to do the best they could for themselves.[2] The smaller grains were not procurable. From this state of things great distress was beginning to be felt; people began to flock into the city for relief; cultivators with their cattle and families left their homes to wander they knew not whither in search of food or employment. Children are reported to have been sold by their parents in the city of Jhansi. Small-pox raged during the first six months of 1869. Sunstroke[3] carried off numbers of enfeebled wretches; men came in weary and weak and fasting, took a long draught of water and died. Cholera appeared with the rainy season, and fever of a malignant type, the usual attendant of scanty and inferior food, doubled the tale of victims. 20,300 died in the district of Jhansi in 1869, and 3,180 only in 1868."

"In Lullutpore (also in the Bundelcund zone), of 233,000 cattle 95,000, or 41 per cent. died.[4] Some were sent off to the jungles, others were driven to shift for themselves in the barren fields. The change to abundance of grass and water upon the setting-in of the rains in 1869 is said to have destroyed numbers. The stench arising from thousands of carcases polluted the air, and contributed to the outbreak of cholera, which was the last visitation. £8,800 was

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[1] Henvey, p. 2 (abridged).
[2] Commissioner of Jhansi. Henvey, p. 63.
[3] Ibid. Henvey, pp. 64–67. [4] Ibid. p. 77.

advanced for useful works, and £7,000 for seed and cattle. But the advances went to buy bread and preserve life; consequently wells have not been sunk; cattle have not been replaced; want of men and cattle prevents cultivation; sixty per cent. of the land revenue demands were suspended."

"In Ajmere (a district since separated from the North-Western Provinces), dependent on tank irrigation, which necessarily failed when there was no rain, the loss of life was estimated at 106,000, or 25 per cent. of the population.[1] The famine was so fearful, and the distress so wide-spread, that the population of whole districts gave themselves up to despair, which was of itself but a symptom of the disease of starvation. They would not leave their villages or families to seek sustenance, or left so late that they died on the way."

"Another of the disastrous consequences (says the reporter) in this part of India, is the loss of plough cattle.[2] When grass fails, and the slender stocks of fodder are consumed, the cattle die, or are sold to butchers; and if the cattle perish, cultivation is impossible."

The foregoing extracts relate to the unirrigated regions in the Bundelcund zone. The following describe the condition, at the same period, of the irrigated portion of the 'Plains'[3]:—

"The canals where they existed were the life of the country. Unhappily, however, there were considerable tracts within the area of drought which possessed no such advantages. The history of the famine in those parts has been told. That the benefits conferred by canals, judiciously and energetically worked, were enormous, will be apprehended from the following plain statement of facts."

"The area thus irrigated in 1868–69 was 1,442,000 acres against 983,000, the maximum of any preceding year. Of this great area 598,000 acres were cultivated with wheat, and 257,500 with barley: 1,190,000 acres, or 82 per cent., were cultivated with food crops for man and beast. The crops exclusively devoted to human food yielded sustenance for more than 1½ million of adults for a whole year."

The Report concludes, "The produce saved by canals has been computed at half-a-million tons, but the estimate of district officers is still higher, and their valuation amounts to five millions sterling."[4] In former famines there was no food within possible

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[1] Commissioner of Jhansi. Henvey, p. 97. [2] Henvey, p. 126.
[3] Ibid., p. 113. [4] Ibid., p. 114.

reach of the afflicted districts. In 1868–69 the development of irrigation created a surplus stock in the plains of the north-west, which an arterial railway carried east and west with great facility. But other means of transport were insufficient to carry the entire food of a population; and unfortunately Jhansi, Lullutpore, and Ajmere, the provinces most remote from railways, were also dependent entirely on rainfall for their sustenance.

The following extracts from the Chief Engineer's Report were adopted and published by Government in the Gazette of India:—

"The irrigated tracts of the Doab (or central portion of the plains included between the rivers Ganges and Jumna) were the heart of the province, from which surplus food flowed out by railways westward to the Cis-Sutlej States, in which there was no harvest to reap; and southward by never-ending trains of carts and camels to Bundelcund, Ajmere, and Rajpootana, where no grain was ever sown. Under Providence, a famine was averted in the Cis-Sutlej States and the Doab by the combined action of railways and canals."

"But besides producing food for the support of human life, canal irrigation created sustenance for cattle which was producible by no other means; and at a crisis when wells failed in well-irrigated districts, and herbage and fodder depended on abundant water, the cattle of the Doab were saved, strong to labour in the work of the following harvests; whilst elsewhere those harvests also were reduced, by the want of cattle which had been swept off by the drought."

"And lastly, canal cultivators became rich, whilst others suffered, because they realised both large crops and high prices; the payment of land revenue was assured, the breaking up of communities, the unsettlement of the social system of the country, the loss and dispersion of property, which famine entails, were averted; and a vast sacrifice of life prevented, which, but for the extension of canal irrigation, must have occurred in 1868-69 as it had occurred in the same districts in 1837-38. I trust these results may be pondered by those who recommend dependence on the irrigation to be derived from wells in a year of serious drought."

Having thus established that canal irrigation in the North-Western Provinces is necessary to good administration, the scheme which has been projected for turning all available waters to the greatest advantage will now be described.

It will be seen from the map (Plate 6) that the greater part of the largest and most important of the three zones, that of the 'Plains,' is included between the rivers Ganges and Jumna, which rising in the heart of the Himalaya mountains, debouch in the same latitude, at a distance of 50 miles apart.

The characteristics of these rivers are identical; both rise in eternal snows, and both receive large affluents before they leave the mountains. The drainage area of the Ganges is 11,200 square miles, and that of the Jumna is 7,800 square miles. In great floods, which are of very rare occurrence, they severally discharge about 230,000 cubic feet per second and 160,000 cubic feet per second. From the middle of October the waters diminish, and by the middle of January, generally sink to about 4,000 cubic feet per second in the Ganges and to about 2,000 cubic feet per second in the Jumna, at about which amount they continue until the end of March, when they are affected by the melting of the snows on the mountains: thenceforward increasing in volume, until supplemented by the south-west monsoon.

The rivers leave the Himalaya on boulder beds, sloping 8 ft. to 10 ft. per mile. After a few miles the boulders terminate, and thenceforward nothing but fine sand is found in the beds. These naturally become troughs in wide valleys, in which the courses of the rivers are constantly varying. The surface of the rivers, beyond the end of the boulder formation, is generally about 40 ft. below the adjacent country.

As it is desirable to commence irrigation as near the foot of the mountains as possible, the head works of the Ganges and of the Jumna Canals have been fixed on the boulder portions of the river beds; partly on account of their stability, partly to obtain for the water entire command of the country, and partly to take advantage of the circumstance that the river bed is there broken by islands into numerous channels of different levels, affording facilities for leading and regulating the supply. All the water in the rivers in January is required, and consequently it is necessary to construct dams across the perennial streams in order to obtain control of the supply. At certain times the whole of the visible water is turned out of the river beds into the canals. Temporary dams of crib-work boulders and shingle, which are skillfully constructed in the violent currents of the rivers, and are swept away annually when the water rises above a certain point, are found to be the cheapest and most suitable for the purpose of holding up and diverting the water; whilst masonry structures are preferred for the regulation of supply channels.

The Ganges Canal, designed and opened by Sir Proby Cautley

—an engineer whose genial love of his work for the sake of its benefit to humanity is traceable in all his schemes—is the largest of the works which have been undertaken in Northern India; and possibly is the largest work of the kind in the world. The width of the bed at the Solāni Aqueduct—18 miles from the head—is 164 ft., and the depth 10 ft. The main channel is 348 miles in length, and is navigable throughout; the several branches, each equal to considerable rivers, are 306 miles in aggregate length, and the main distributaries, constructed and maintained by Government, measure 3,071 miles. Each of these main distributaries is a small canal, with masonry outlets, falls and bridges as requisite. The minor distributaries, leading to individual villages and estates, and the field water-courses, are constructed and maintained by those concerned. A carriage-road is kept up on all main and branch canals, and plantations of timber trees, which will shortly be of great value, border the canals on both banks throughout their length.

The irrigation commences 22 miles below the heads, and is diffused over an area 320 miles long by about 50 miles wide. The canal in the first 18 miles of its course crosses a considerable amount of Sub-Himalayan drainage, some of which is passed through the canal by waste weirs, some over the canal on super-passages, and some under the canal by sub-drains. The works of this section are of an important character, and are chiefly constructed on block-foundations perforated with wells, by means of which they were sunk in running sand, or other unstable soil, until a hard stratum was reached or until they would sink no more.

The Solāni Aqueduct, and its embanked approach, span a valley 2½ miles in width. Its foundations are 20 ft. below the surface: they do not rest on any hard stratum, and the weight of this ponderous structure is entirely supported by the pressure and friction of wet sand. No subsidence has occurred in any part of the aqueduct. The slope of the country in the upper part of its course is much more rapid than that given to the canal bed. The difference has been overcome by masonry 'ogee falls' at convenient points, which also are considerable works. It is found that the ogee fall creates a great disturbance at the tail when carrying a considerable volume of water, and vertical weirs, with long crests, are being built on the new canals. The great need in all falls is to insure a good cushion of water for the water to tumble upon.

The merit of the original works in the upper part of the Ganges Canal is greatly enhanced by the difficulty of the conditions under which they were built. In 1842, when the works were commenced, there was not a steam-engine at work nearer than Calcutta, 1,100 miles from the head of the canal; and so difficult was transport at that period, that heavy materials from Calcutta were six months on the way, and were liable to risk of loss on the journey; whilst fifteen months elapsed before an indent on England could be realised. No stone was procurable for the works, and great difficulty was found in obtaining fuel sufficient for the large requirement of brickmaking. Brickmakers, carpenters, blacksmiths, bricklayers, and various handicraftsmen had to be educated to supply the large demand.

Below the region of rapid slope the works, although very numerous, are seldom of a special character. No irrigation is allowed directly from main canals or branches; the detailed distribution is made from heads placed in the banks of main distributaries or rājbuhas. A canal officer, besides supervising the construction and maintenance of works, controls the irrigation of his subdivision; it is his business to make the water he receives go as far as possible, and to see that the distribution is just and equitable. He has also some magisterial powers for the prevention of breaches of canal-laws, and it is his business to settle disputes of measurements, and questions whether irrigation has been duly given or not, in which he is much aided by his professional acquirements. His life is consequently a very active one: he travels a great deal, and lives much amongst the people, to whom he is at all times accessible.

Plans of intrusting the distribution to those interested have not as yet met with success. The horary system of Spain and Lombardy cannot be practised in a country where there are no clocks, and where the people are so insufficiently accustomed to the liberty they enjoy under British rule as to submit meekly to the extortions of any one more powerful than themselves, whether neighbours or subordinate officials. All lands irrigated in each harvest are assessed with water-rates fixed for each description of crops, which are collected by the revenue officers and credited to the Canals. This is the only direct payment exacted for irrigation; but as the land revenue consists, as before stated, of half the income of an estate, it follows that when that income is enhanced by irrigation (or other means), the land revenue shares in the benefit. This difference between the land revenue of irrigated and unirrigated lands is termed 'the indirect revenue' of canals. It is credited in the public accounts as Land Revenue, but the Canal Administration shows the amount in its returns.

The earning of a cubic foot of water per second on the Ganges

Canal in 1870–71 was £44 per annum; on the Eastern Jumna, £59 per annum. The difference in value is owing to the latter canal having been longer at work and being more completely developed than the former.

The net income of all the canals in the North-Western Provinces, after payment of working expenses in 1870–71, was £182,437, being 6·64 per cent. on the capital cost of £2,714,631. So that canal irrigation makes an excellent return to the Government in money, at the same time that it increases the wealth of the country, and affords security against misery and famine; but it would hardly remunerate Joint Stock Companies which do not profit by the indirect results.

The Ganges Canal has not been largely used for navigation, in consequence of the rapidity of its current. Measures are now in course of adoption to reduce the slope, and these, it is hoped, will lead to an increase of traffic. In the absence of commercial demand, the water-power, estimated at 30,000 horses, has not been, as yet, turned to much account. A commencement has been made by leasing water-power to persons competent to utilise it, and there is great room for enterprise in this direction.

The Eastern Jumna Canal is the type on which the Ganges Canal was constructed, with such improvements as were suggested by the experience then acquired. It was intended originally that the Ganges Canal should ultimately be largely extended, but the demand for water in the districts to which it is already conveyed has so greatly exceeded anticipation, that there is none available for extensions. The supply at the head, now hardly sufficient to meet demands in dry weather, cannot be increased; nor if it were increased could the capacity of the canal be conveniently enlarged. But whilst the Ganges in dry weather is apparently drained dry at the canal heads, a considerable amount of water filters through the boulder formation. It has therefore been determined to construct a weir across the Ganges, near Rājghāt, where the Oude and Rohilkund Railway crosses the river, and to carry the Lower Ganges Canal and its distributaries on the alignments shown on Plate 6. Feeders are taken into the existing Ganges Canal, about 140 miles above the present termination; whereby the upper sources will be relieved of that extent of duty, and the whole of the large area over which the old and new canals extend will be irrigated annually to the extent of 35 per cent. of its acreage of cultivation, an amount sufficient to secure the country from scarcity.

The Lower Ganges Canal is just now being commenced with a discharging capacity equal to that of the Upper Canal, namely, 6,500 cubic feet per second. Its estimated cost is £1,825,000; the original Ganges Canal will cost, when finished, £3,000,000, and the whole combined system will no doubt be completed for £5,000,000. There is reason to expect an ultimate return of 13 per cent. on the undertaking, but years must elapse before so large a profit can be realised.

The proposed weir across the Ganges at Rājghāt is a somewhat formidable undertaking. The bed of the river is running sand of great depth, which will scour considerably, and no heavy material is available save what is manufactured on the banks. The width of the flood stream is 2,100 ft., and the weir will be made 4,000 ft. in length.

On the right bank of the Jumna below Delhi, lie the districts of Muttra and Agra, which are greatly in need of irrigation by reason of the depth of the water below the surface. The water, moreover, is generally brackish. The soil is a clay loam, which, when irrigated, will be very productive.

The Agra Canal has accordingly been projected for the irrigation of these districts.

A weir has been built, 2,428 ft. long, across the Jumna at Okhla, at a point where a spur of quartz running out from the Aravali range abuts upon the river.

Here a different design has been adopted. Stone being abundant, reliance has been placed upon breadth instead of depth. The work has no foundations. It consists of two parallel masonry walls, 2,428 ft. long, running from end to end of the weir, of which the footings rest on the fine sand of the river bed at low-water surface level. Between these walls, which are 26 ft. apart, stone is packed and a slope of stone constructed, up stream, with a base of 40 ft., and down stream with a base of 200 ft. The height of the crest of the weir above low-water surface is 10 ft. Scouring sluices are constructed on one flank of the weir, to keep a clear channel in front of the canal head.

The weir, when 9 ft. high, was tried last year by the greatest floods ever known on the Jumna. The results were most satisfactory; no serious damage was done, and no settlement was perceptible in the down stream long wall, which had been completed; but injury occurred to the up stream wall, which was left unfinished and insufficiently protected against the cross scour caused by the under-sluices. The depth of water on the crest of the weir was 5·25 ft., the velocity on the crest, 9·33 ft. per second, and at a point 40 ft. lower down the slope it was 18 ft. per second. The bed of the river had scoured 3 ft. on the down-stream side of the weir, and the 'toe' of the weir had also settled to the same level.

The Agra canal has a maximum discharging capacity of 2,000 cubic feet per second. It is designed to irrigate 350,000 acres, and its navigation will probably be important.

For the benefit of the portion of the zone of the 'Plains' east of the river Ganges, an Eastern Ganges Canal is about to be constructed, taken off at the bottom of the boulder formation. It will water 450,000 acres, equal to 35 per cent. of the area of the districts commanded, and minor canals from the Rāmgunga and Buhalla rivers will complete the requirements of the upper portion of this zone.

In the Sub-Himalayan zone the first requisite is to remove the dams which obstruct the channels of the rivers and water-log the country. At the same time small canals will be made upon each of the water-sheds, and will be supplied from single weirs placed as high as possible up the rivers. By these means the drainage of the country will be effected, and an increased supply of water for irrigation purposes obtained. This scheme will soon be profitable, because the works can be speedily completed.

Great difficulties presented themselves in dealing with the Bundelcund zone; not for want of rivers, for the Keyn, the Betwa, and the Dussan, carry large volumes of water, but at the wrong time. Rising in the high lands of Central India, and dependent solely on rainfall, these rivers leap down to the level of the Jumna in alternate pools and rapids; and as both the country which they drain, and the beds on which they run, are chiefly granite and trap, the rainfall is collected and carried off with marvellous rapidity, leaving the river-beds almost dry soon after the rain has ceased. The channel in which the river Betwa flows is 1,450 ft. wide by 61 ft. deep near the town of Jhansi. The highest floods of the river, which fill it brim-full, generally occur in July or August, and measure above 700,000 cubic feet per second. Yet, by the end of October the supply dwindles to 160 cubic feet per second, and by the month of January it is reduced to 50 cubic feet per second, passing through a notch 6 ft. wide. There is no water at all for sugar and indigo from February to June, and when the river is full, water is not wanted for irrigation.

To irrigate the whole area which the river commands, it would be necessary to store water in the bed of the river, by constructing a series of dams at the lower ends of the pools. But the cost would be prohibitive. It has been therefore determined to exclude from irrigation the rich black cotton soils which form half the area, and, excepting in extraordinarily dry seasons, produce crops without artificial moisture. The average water available will just suffice to mature the wheat and other winter crops on the rest of the country.

A weir 26 ft. high must be built across the River Betwa, in order to raise the supply and reduce the depth of excavation at the head of the canal to convenient limits. The Betwa Canal will water 120,000 acres in the Jaloun and Humeerpore districts; two-thirds fully, and one-third only at ploughing and seed time. The estimated cost is £170,000, and the anticipated return from water-rate only, 10 per cent.

In the river Dussan the construction of a weir 15 ft. average height, and 45 ft. above the lowest part of the channel, will water the whole winter cultivation which it commands, amounting to 68,000 acres in the Humeerpore district. The cost is estimated at £124,000, and the returns at 11 per cent.

On the river Keyn it is necessary to raise a dam 85 ft. high, in order to bring the supply near the surface. Fortunately, the rapid slope of this river, and the depth of the trough in which it runs, enables this to be done without submerging the country. The canal will cost £130,000, and return 11 per cent.

These three weirs will stand on barriers of granite, crossing the rivers at the selected sites, and will be built of that material.

Lastly, fifteen considerable lakes in Bundelcund, which have been formed in natural reservoirs, will shortly be made available to water 22,000 acres, and to return £2,500 per annum on a capital expenditure of £8,200.

By these means 700,000 acres will be annually watered in Bundelcund and Jhansi; an area sufficient to ensure the province against famine, and, it is hoped, to restore it to its pristine fertility.

Having thus described the means provided for irrigation in the North-Western Provinces, it now remains to explain the financial results. In 1870–71 upwards of 1,000,000 acres were irrigated from existing works, which afforded a net return of £182,500. The capital expended up to the end of that year on all works in operation, good and bad, amounted to £2,747,000; the net profit on the whole was 6·64 per cent. The further undertakings described will add £4,690,000 to the capital, which will then amount to about seven and a half millions sterling. The returns, actual and estimated, are expected to rise to 12 per cent. on the capital, when the canals shall be fully developed; and this development will be more rapid than it has been, because the value of water is now fully appreciated, whereas in early days the people had to be pressed to take it; also because distributaries are now made at the same time as other works, whereas formerly they were not begun until a canal was otherwise completed; and because experience has taught economy in the distribution of water.

This concludes the narrative of proceedings in the North-Western Provinces. A large system of canals has been projected for the irrigation of the neighbouring province of Oude, from the River Sardah, which will extend to some parts of the Benares division. Those works are under the direction of the Oude Administration.

The physical geography of the Punjâb is much the same as that of the North-Western Provinces. There is a zone of 40 inches rainfall at the foot of the Himalaya, bounded on the south by a belt of 16 inches rainfall. The remaining country to the south is almost rainless. The principal canal in operation is the Western Jumna, an old Mahomedan work, which, like the Eastern Jumna, pays extremely well. Before the annexation of the Punjâb this canal was under the government of the North-Western Provinces, and has been at work under British direction for upwards of fifty years. It has paid nearly two million sterling clear profit, after repaying capital. The Baree Doab Canal, taken from the Ravee, was constructed on the model of the Ganges Canal. Up to the present time it has been contending with the difficulties which beset the first undertaking in a new country, but contending successfully, and gradually making way.

There are inundation canals on the Indus, the Chenab, and the Sutlej, which, as their names imply, depend on the floods for their supply. They are profitable to the state, and beneficial to the people.

The Sirhind Canal, now under construction, is a work of first-class magnitude and importance: it will cost about two millions sterling, and irrigate a country where rain is now very scarce. It is calculated to pay about 9 per cent. Another project is in execution for the irrigation of the Peshawur Valley. Whilst the characteristics of irrigation in the North-Western Provinces, Oude, and the Punjâb, are very much alike, they differ largely from the conditions current in Madras. In Northern India irrigation is carried over the whole country; crops are watered both in winter and summer, and the irrigation affords the greatest benefit in the winter, when there is little or no rain. In Madras, on the other hand, canal irrigation is only effected during the rainy season, when rivers are full, and is confined to the deltas of the larger rivers.

In Scinde, some few canals are in operation, and others are under construction; but they have not been long enough established to produce any important financial results.

It may be interesting to the profession to know that about 250 engineers, of and above the rank of assistant-engineers, are employed under the Indian Department of Irrigation in protecting the people amongst whom they live from scarcity and famine, and in developing the advancement and prosperity of the country.

A number of interesting matters, engineering, agricultural, and social, relating to the subject, have of necessity remained unnoticed in this rapid sketch, which has been limited to an outline intended to show the soundness of the course adopted by the Government of India, and the magnitude of the interests intrusted to the engineers employed in the execution of the works.

The Paper is illustrated by a series of diagrams, from which Plate 6 has been compiled.

IRRIGATION IN NORTHERN INDIA.

SKETCH MAP OF CANALS EXISTING AND UNDER CONSTRUCTION IN THE NORTH WEST PROVINCES.

Scale of Miles.

Colonel Greathed stated that the bed of the river Jumna where the weir was constructed at Okhla consisted of nothing but fine sand. There was a considerable stream of water passing down during the rainy season. A different form of weir had been considered more suitable for the head of the Lower Ganges Canal at Rājghāt, where no stone was available. Continuous experience had shown that the best safeguard for a weir was to reduce, as far as possible, the velocity of water passing over it by extending its length, as thereby the dangerous action of the water upon the soft sand of the river bed was mitigated. But scour, and depression of the surface and bed of a river with such a bottom, must occur. It was necessary to defend the main body of a weir by a long talus. The sandy beds of these rivers were always raised on the up-stream side, consequently that portion of the work would be safe from scour. The main defence was presented by a line of contiguous deep wells on the down-stream side of the weir, which were protected by a talus of crib-work of rough boulder stones. The foundation of the Okhla weir across the Jumna was on the level of the top surface of the sand, or actual bed. The slope on the up-stream side of the weir was 4 to 1. The longitudinal walls were of rubble masonry.

Mr. J. F. Bateman said everybody present would recognise in the works carried out by the Indian Government the great benefit that had been conferred upon the country at large. The Paper was very interesting, but it was almost impossible to have it discussed by the Institution. There were no engineering details beyond a general description of canals of vast magnitude which irrigated a certain extent of country, and the only subject which could come under the ordinary process of discussion was the construction of the weir at Okhla. He confessed he had not obtained that accurate conception of the mode in which the weir was constructed to enable him to offer any critical observations upon it. He understood that on the up-stream side it had a slope of 1 in 4, and that there were continuous cross walls, with a broad base formed of dry rubble, and then a long slope of dry rubble on the down-stream side. It appeared that there was a head of water of 5 ft. flowing over the crest of the weir at a velocity of 9 ft. per second or 10 ft. per second at one part, and which increased to 18 ft. per second lower down. Such information as this was useful and valuable as a record of practical construction and working. The weir proposed to be erected at Rājghāt appeared to be a cylinder construction of wells sunk into the sand, filled apparently with concrete or other material; but in this case also the Paper had not conveyed to his mind any impression as to the mode of construction. There could be no question as to the importance of irrigation works, and the great benefit they were likely to confer upon the country; and the Institution could not but feel indebted to the gallant officer for having taken the trouble to put such a series of details on record; but, practically, the Paper was one which did not admit of much discussion.

Mr. Vignoles said that the Paper contained a mass of valuable topographical information, but there was not a sufficient amount of engineering details to discuss the most interesting point which had been raised, namely, the best form of construction for a weir where there was a large body of water tumbling over it at a great velocity.

Colonel Greathed said he feared he had not sufficient materials at hand to enable him speedily to afford more precise details. The great extent of the district over which the works were spread rendered it impracticable to review within the limits of one Paper the general scope of the scheme, and, at the same time, to furnish the details of works of construction. It had appeared to him that the proper course, in the first instance, was to describe the principles on which the scheme was founded, and thus to establish a base for further discussion on specific works and details. The weir proposed to be erected at Rājghāt, at the head of the Lower Ganges Canal, consisted of a vertical wall of brick or rubble masonry, faced with ashlar, constructed to raise the level of water in the river 6 ft. 6 in., and thereby to insure a constant supply to the canal heads which are placed just above it. The river fell over the wall upon a countersunk ashlar platform; a row of continuous wells of moderate depth would be constructed under the vertical wall, and a similar row of deep wells along the tail of the platform. A slope of crib boxes filled with heavy material was proposed for the down-stream protection, and a dry stone slope for the up-stream side of the wall. The flooring of the weir would be of ashlar. At a future time he proposed to present to the Institution accurate drawings of the weirs as constructed, and of the effect upon the Okhla weir of the extraordinary floods of 1871. The down-stream cross wall was then completed to full height, but the up-stream wall was not commenced. At that time, to protect the cross wall, the slopes of dry stone had been carried to about 15 to 1 on the down-stream side, and to about 4 to 1 on the up-stream side. The effect of the flood was to silt up the bed to the level of the up-stream wall, and no damage was done to the boulder talus of 1 in 4; but from the point at which the velocity increased to 18 ft. per second over the weir. The surface of the down-stream slope was scored by holes, or sometimes by cuts carried down to the tail of the weir, where there was a considerable hole. The safety of the weir, however, was at no time seriously threatened. The holes were not of great depth, and at the end of the season were repaired at small expense.

Mr. Barlow inquired whether the flat slope of the weir was considered necessary as the result of previous experience in India, or was it made for the first time in the case of the Okhla weir?

Colonel Greathed replied it was not the first time the slope was carried to that extent. The slopes of the weirs of the Kistnah and Godavery were made much steeper. The stone facings of those works were, if he could trust to recollection, cramped and laid in mortar, whereas, at Okhla, the face blocks were merely packed dry as quarried. The height of those works was also considerably less than that of the weir at Okhla. The annual cost of repairs of the Kistnah and Godavery weirs had at first been great, and consisted chiefly of additions to the tail of the weir. Some stones had been cut away, others had been thrown in, and in that way the slope was prolonged. In the Pennair river, when the weir was carried away for the first time, the down-stream slope section was increased to a slope of 1 in 10. After the second failure the slope was altered to 1 in 20, and at that point it stood. As the conditions of the Pennair river closely resembled those of the Jumna, the regimen which had succeeded in the first case was adopted for the other. There was a little falling in at the 'toe' of such weirs, where the slope was of small thickness. The great object was to keep the scour off the main body of the works.

Mr. Parkes asked what was the position of the weirs with regard to the courses of the rivers, and, severally, their lengths as compared with the general breadths at their sites?

Colonel Greathed replied, the weirs had been placed at right angles to the rivers. The length of the Okhla weir was rather in excess of the width of the extreme flood level, and was so designed to reduce the velocity of the water going over, as much as possible. In the case of the proposed weir at Rājghāt, the length of the weir was less than the average width of the river bed, but was in excess of the width of the running water in highest floods, and was so designed that the maximum velocity of the water going over it should be under 8 ft. per second. The object of the weir was to raise the water 6½ ft., and to save that amount of digging for the first twenty miles. The Okhla weir, as constructed, raised the surface of the water 8 ft. 6 in. That would be the level of the ordinary supply of the canal; the cill of which was fixed $11\frac{1}{2}$ ft. above the original river bed in order to lessen the influx of silt. When the water in the river was above 8 ft. 6 in. it tumbled over the weir, and, practically, it kept at, or above, that level during the low-water season. In dry weather an increased supply would be obtained by raising the crest of the weir $1\frac{1}{2}$ ft. by planks or movable shutters.

In answer to a question he stated that the Agra Canal weir at Okhla was in operation, and the lower Ganges Canal weir at Rājghāt had just been commenced. Much discussion had taken place as to whether it was desirable to give the greatest support to a weir on the up-stream side or on the down-stream side. Experience had shown that, under the circumstances which affected the Rājghāt weir, the strain was caused by the retrogression of the river bed on the down-stream side. But, under other circumstances of soil and slope, a different conclusion might be arrived at. In the case under discussion the river bed consisted of fine sand only. It was found that the bed and surface of water on the down-stream side of the weir had been lowered 3 ft. in consequence of its construction, and the retrogression which this alteration tended to cause required to be carefully checked. At Okhla, a supply of stone on the spot rendered the broad construction preferable. Where material was not abundant safety must be sought in deep foundations capable themselves of resisting retrogressive action.

Mr. Brunlees said it would be interesting to have a description of the construction of the portion of the weir at Okhla, over which there was a velocity of 18 ft. per second. He hoped that the Author would favour the Meeting with a sketch of it, as he was sure it would be a matter of interest to all.

Mr. Redman said it was to be regretted that the Paper had not been accompanied by general cross-sections of some of the leading arterial canals, showing their formation in cutting and embankment; and, undoubtedly, there was a paucity of that technical information which should have illustrated the subject. But it might reasonably be assumed that the Author only intended the present as the first of a series. When the magnitude of the works and the great number of engineers employed upon them was considered, it almost read like a fairy tale, to find that over so extensive a tract of country, canals, costing, as these had done, large sums of money, yielded so high a rate of interest as $6\frac{1}{2}$ per cent., and at the same time conferred incalculable indirect benefits upon the country.

The weir which had been erected at Okhla was certainly a gigantic work. It was 2,000 ft. in length—double the length of London Bridge—constructed across a large river. The question at once suggested was, what were the functions of the two vertical walls in the centre of its section? He took it for granted that they performed two important duties, both during the course of construction and also when the dam was finished. In construction they held up the crest of the work, and formed the nucleus of the dam; and when finished, they undoubtedly prevented the spread of one of those breaches which occasionally occurred on the lower slope, as described by the Author; and, so far, they had proved conservative. He did not consider the precise formation of the 'toe' of the slope in a weir of that construction to be of much importance. Undoubtedly, the 'toe' of the slope, in an ordinary embankment for sea defences or reservoirs, with a slope of 4 to 1 or 5 to 1, did perform important functions, and, unless it was very carefully made, the wall was liable to fall, from inattention in that particular. Many engineers sheet-piled the 'toe' of the slope; others dug a trench and filled it in with a mass of concreted matter, forming a 'toe' on which the slope of the wall at a steep incline rested, and prevented the tendency of the wall to slip forward. Again, where exposed to recession of the tide, or in the case of a reservoir with a small amount of water—in either case the wall was liable to be undermined; but in this particular instance those functions were reduced to a minimum; and consequently the slope with an incline like that of 20 to 1 had, in point of fact, very little 'toe' at all.

With reference to the proposed weir at Rājghāt, it appeared that there was a special construction through the heart of the work formed by a series of cylinders. That row of cylinders would perform the same function as the two parallel walls which had been constructed across the river in the case of the Okhla weir. A question had been asked about the upper crest of the proposed weir at Rājghāt. He assumed that it had been planned, to a certain extent, to save the expense of carrying the work to the top of the flood water, and of forming a tumbling over-fall. If his assumption was correct, the series of cylinders would perform a separate duty in controlling any breach that might occur in the surface. Again, when the water was flowing over at the flood level, that duty would be reduced to a minimum.

In conclusion, he would suggest to the Author that he would confer great benefit upon the Students of the Institution if he would follow up this interesting Paper by accompanying it with more complete engineering details and by general sections of some of the main arterial canals. A series of such documents would add greatly to its value.

Mr. G. B. Bruce said there was considerable difficulty in discussing the Paper, owing to the incompleteness of the engineering details. As regarded the Okhla weir, there was no information given as to the water levels of the river. It appeared that the bed of the river was of fine sand; and it might be that the low-water at certain seasons was just level with the top of the bed, or—as was often the case in Indian rivers—that the low-water level was below the bed. If such was the case, it seemed strange that the cross-walls should not have been sunk below the bed of the river; and under any circumstances, it seemed rather a hazardous experiment to build the centre walls without putting wells under them, or sinking the foundations to a greater depth than had been indicated by the Author.

It had been stated that the slope of the upper section of the apron in the Rājghāt weir was proposed to be only 1 in 4; it was, therefore, a matter of surprise that there was no protection to the 'toe' of that slope, however much such protection might not be required in the lower portion of the apron, carried as it was to such an extent that its formation simply amounted to tumbling in large stones for a great length along the river bed. The entire structure, as proposed by the Author, seemed peculiarly venturesome. The upper row of brick cylinders as well as the lower one ought to have been carried down deeper, on to the clay stratum, to which level, it had been stated, scour occasionally took place during floods. If this was not done, he should expect to see the upper wall fail, resting as it did on shifting sand very liable to scour under the most ordinary circumstances. He did not consider the weir would be safe with the upper cylinders carried down to so shallow a depth; and he thought that it would have been wise and economical to have carried them to the same depth as the lower walls, thus converting them into two cross-walls, and filling the interval with concrete, protected with stone above, and below at the 'toe' of the slope. If built as proposed by the Author, he believed that in a heavy flood the upper walls would be scoured bodily out and carried over the lower line of walls, which, in their turn, would be swept away in the general destruction.

With regard to what had been said about the rate of interest which was returned to the Government by irrigation works in India, he was glad to hear that they were so productive as to lead the Government to carry them out to so large an extent; but still he took with great hesitation the account of the actual cost of Government works. He thought in India generally that the public did not know exactly the cost of public works: that was, they did not know what was put into the estimate, and what was kept outside of it, or what were the general charges of the military officers and other persons in supervision, whose time and expenses did not form an ingredient in the work. If he recollected aright, there was some Mahomedan work, which was stated to have returned a clear profit of two millions; but it did not appear that any one knew what it originally cost; and, consequently, any estimate of the percentage of profit returned must be a pure assumption. There was a great difference between the manner in which Government accounts were kept and those of a joint-stock company. In the latter case, everything, including all general charges, was placed to the account of the works constructed.

Mr. BALDWIN LATHAM observed, that the Paper was one of considerable interest and importance, as showing the extent to which irrigation works had been developed in India. Apart from the great agricultural results obtained from irrigation, it could not be overlooked that, with the extension of the works, sickness and death had been materially increased, especially in districts in which certain processes of irrigation were carried on. It was well known in India, Egypt, Piedmont, Lombardy, and Southern France, that such irrigation as was brought into operation in the cultivation of rice, developed or augmented a certain class of disease; while, on the other hand, irrigation, by a different method, or in which the irrigated meadows were arranged with sloping surfaces, as in the cultivation of marcite, no baneful results had followed; hence, laws and regulations had been introduced into many countries restricting the cultivation of rice to certain distances from populous places, but permitting other descriptions of irrigation to be carried on in their immediate vicinities. In the year 1845, a Commission was appointed by the Governor-General of India, to inquire into the cause of the unhealthiness of certain irrigated districts. That Commission was also required to report upon the probable effects of the introduction of irrigation, in the district described in the Paper as lying between the rivers Ganges and Jumna. The results of that investigation were recorded in Capt. Baird Smith's "Italian Irrigation,"[1] and the conclusion then arrived at distinctly pointed out that in the districts "under the influence of the existing canals, sickness had been

[1] *Vide* "Italian Irrigation," by R. Baird Smith, F.G.S., Captain of Engineers, Bengal Presidency. Edinburgh and London, 1855. Vol. ii., p. 359 *et seq.*

largely developed." The Commissioners, however, pointed out that this was in a great measure due, not so much to the results of irrigation, as to the fact that the natural drainage of the country was impeded, and tracts of swampy land created which diffused a malarious influence around.

In the cultivation of rice, the system adopted was that of surrounding the irrigated plot by a small embankment, turning the water within the enclosure; and, as a rule, such water had no chance of escape except by evaporation through the rice-plant or from the water surface. Irrigation works laid out with surface slopes, and a current of water flowing over the surface, prevented that stagnation which, in the case of rice, had been shown to be detrimental to health. What were the precise differences of the application of water in rice irrigation and those in irrigation works, where a constant current was kept moving, he had made a subject for investigation, and would proceed to give the results of some experiments, which would show that where a surface velocity was created, that velocity would promote a circulation of water through the soil, a matter of no small importance, as by that circulation manurial matters were equally distributed, while other matters, not required by the plant, were removed, which, if allowed to stagnate, produced those ill-effects shown when cultivating rice. He had been led to undertake those experiments in consequence of having observed in sewage-irrigated fields, that if sewage was placed on a field laid out with surface slopes, and the field was perfectly saturated with water, as in time of heavy rainfall, the sewage displaced the rainfall which had saturated the soil, taking its place; and that subsequently it appeared that each increment of sewage passed on the surface of the field displaced the previous increment, and so a circulation of water was carried on through the soil. In order to put these views to the test he had constructed a water-tight glass tank, 5 ft. long, 12 in. deep, and 6 in. wide. The tank had then placed in it a solution of perchloride of iron of the specific gravity 1·027. It was then slowly filled with fine silver sand, and after being allowed to rest for some time in order to obtain perfect solidification of the materials, the tank was placed at an inclination of 1 in 100. An infusion of nut-galls of the specific gravity of 1·002 was allowed to pass slowly on to the tank, at its upper end, the infusion being dropped into a small metallic trough, laid across the glass tank so as to prevent the disturbance of the surface of the sand by the passing of the infusion of galls on to it.

In Fig. 1 the point T showed the position of the trough receiving the infusion of gall. The two liquors used were adopted on account of their mixture forming a tannate of iron, or ink, which portrayed a perfect diagram at every stage of the experiment. The light lines showed the effect produced by the infusion of galls after each 24 hours' experiment, and the total quantity of solution passed from the commencement of the experiment. It would be seen that by natural gravity the infusion of galls could not be passed to a greater depth than 0·6 in., at the upper end of the tank, and that gradually the depth diminished to nothing at the lower end. After 48 pints of infusion were passed on to the tank the infusion reached the bottom of the tank, and from the direction of the curved lines it was natural to infer that, had the tank been deeper, a greater depth would have been reached. What was singular in the case was that the light gall solution which displaced the iron solution for the space above the lines, marking the point of contact between the two liquors, was found to contain an infusion of galls; and, until the black lines marking the junction between the two liquors reached the lower end of the tank, nothing but a pure uncoloured solution of iron came off, equal in quantity to the gall solution passed on. At the end of the ninth day, instead of an infusion of galls, a solution of perchloride of iron was passed on to the tank. The three dark lines showed the effect produced in those days by reversing the order of the liquors which had been used, and again producing discoloration at the point of junction between the two liquors. This was corroborative of the displacement of the former liquor occupying the interstitial place in the sand. It would be seen that the

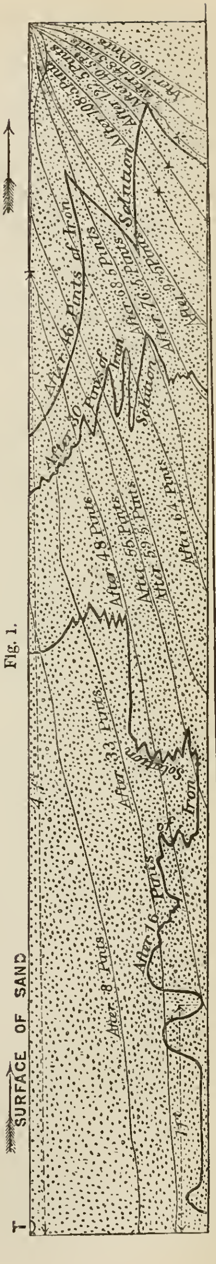

Fig. 1.

Circulation of Water in the Soil.

displacement was much more rapid when a solution of greater specific gravity was used to displace an infusion of less specific gravity. During the three days the iron solution was passed in, it had the effect of driving forward the former infusion of galls in the sand; for, as the three dark lines were being produced, the three light lines marked + + + were also formed. The last two light lines were formed by simply passing water on to the upper end of the tank, which had the effect of pushing forward the infusion of galls. A number of experiments were also made, with different materials, all of which went to show that where there was an inclination of surface or the productions of natural currents over the surface, a circulation through the soil took place.

While these experiments were proceeding another tank was prepared giving the conditions of a rice-irrigated field. In this the sand was saturated with a solution of perchloride of iron, and an infusion of gall passed on to the surface; the tank was kept level, and there was no inclination of the surface and no motion in the liquor over the surface; and it was found that after six months' contact, discoloration of the sand had not taken place to a greater depth than 0·25 in., showing that there had been no displacement of the water occupying the interstitial space in the sand. What could be the precise cause of these results, except circulation, it was difficult to conceive. It might therefore be assumed that when there was no motion in the liquor over the surface there was no penetration into the soil; but that by an inclination of surface producing a current, however small, that current appeared to have the power of putting in circulation the water occupying the interstitial space of the soil. The curved lines in Fig. 1 represented the different rates of velocity within the interstices of the sand, at various depths from the surface. For example, at the end of the third day it would be seen that, while the water had flowed 4 ft. through the surface of the sand, it had only flowed a distance of 1 ft. at the level of the bottom of the tank; showing that the velocity of the surface was 4 times that at the bottom of the tank. From these experiments he had drawn the conclusion, that rice irrigation differed from ordinary irrigation, where the fields were laid out with slopes so as to create a velocity of the surface, as much as a stagnant swamp can differ from a running stream; and he thought that they further demonstrated that, if it was possible, by any means, to establish such a system of irrigation in the cultivation of rice, whereby a circulation of water could be promoted through the soil, that class of irrigation could be deprived of its noxious influence. The circulation of water through the soil, although never to his knowledge previously established, had a marked beneficial influence on irrigation works, as conclusively shown from the practice adopted for generations in the irrigated districts of Piedmont and Lombardy, where it was customary, as the head-water was left, to increase the natural slope of the irrigated beds, in order to create a greater velocity, and hence a greater circulation through the soil. He might also add, that even rain falling upon the surface of a field having a considerable slope would produce a circulation through the soil; for it was found that an infusion of gall, admitted on to the glass tank, at several points formed a series of curves very similar to cycloidal curves, and that the iron solution was driven out at the lower end of the tank.

Mr. W. Shelford said that he had in his possession a longitudinal section of the river Nene at Sutton Bridge, taken in July, 1847. At that time the present bridge had not been erected, but an older structure occupied its site, and the bed and sides of the river—of sand and silt—having been scoured away, it had become necessary to protect the foundations of the bridge by throwing in stones. At the time the section was taken the stones so thrown in had formed a weir, of a rough character, across the river to the height of some 7 ft. 6 in. above the normal bottom. The river Nene was a tidal river, and at high water of spring tides there was a depth of about 21 ft. over the weir, and at low water of spring tides a depth of about 3 ft. 6 in. The difference of level between the surface of the water on the upper and lower sides of the bridge was about 1 ft. at low water. At a distance of 300 ft. on each side of the weir there was a deep hole, which was 23 ft. below the normal bed, giving on each side a slope of about 1 in 10 from the summit of the weir. At a distance of 600 ft. on each side of the weir the new bed remained undisturbed. The total distance between the two extreme points where disturbance took place being about 1,200 ft.

Mr. J. G. C. C. Godsman considered that the necessity for irrigation works was unhappily too well known to all acquainted with India, each and every one of whom must have often heard the terse but truthful phrase, "Irrigation is life-blood." If the self-constituted rulers of that country did not take care that a sufficient quantity of water was stored up and supplied to the natives, they were responsible for the lives lost by famine. As the question stood at present, it was the duty of engineers to consider how they could most efficiently and economically design and construct works which should—by contributing to their future happiness and prosperity—in some measure, recoup the toiling millions for the fearful amount of taxation which, under British rule, had been exacted from them without adequate return.

The Paper was certainly not one from which much could be learnt by the Students of the Institution who were preparing for Indian appointments. It appeared for the most part to be composed of geographical, meteorological, and statistical extracts, of comparatively little use to those whose duties for many years would necessarily be confined to executing and superintending subordinate works. It was true that some scanty details had been given of the weir in course of construction at Okhla, and of another proposed at Rājghāt. But so far as could be ascertained from the imperfect information before the meeting, both of those models were rather to be avoided than imitated.

About thirty years ago he was employed under the East India Company upon the irrigation works of the Madras Presidency. At that period, with the exception of the Colleroon Annicuts and the works in connection with them, no extensive irrigation works had been undertaken by the Company; and indeed those which had been previously constructed under the native rulers had, in numerous instances, by an unwise economy, been allowed to fall out of repair, and hence into desuetude and decay. It was a melancholy fact that as lands previously watered had been reconverted into jungle whole districts had become deserted and depopulated. The comprehensive accuracy of design exhibited in the more extensive native works, and the thorough economical adaptation of the minor constructions to the several objects in view, showed that the natives must have formerly possessed a thorough practical acquaintance with the leading principles of fresh-water hydronomy. Their clear appreciation of the relative importance of the primary elements of time, height, and volume was strikingly displayed in the accurate manner in which they had determined the exact character and class of works necessary to meet the peculiar exigencies severally involved. Scarcely any changes were required in the levels of the larger channels which they had designed, and their works, although constructed of the most economical materials, had lasted for centuries. A well-known instance of the durability of the native works was afforded in the case of the Grand Annicut, or weir, at the seaward extremity of the island of Seringham. That weir was 1,800 ft. in length, from 40 ft. to 60 ft. in breadth, and its crest was from 15 ft. to 18 ft. above the level of the adjacent bed of the river. Although only built of rough stones of moderate size set in clay, it had withstood the effects of the floods for 1,600 years, a period at the expiration of which few engineers of the present time could reasonably hope their works would exist.

When he was employed in the Madras Presidency there were several systems adopted for dealing with the scour produced by the overfall water from a weir. Some weirs were simply built of rough stones, and others had masonry or brick dams with short masonry aprons, the entire structure being based on foundation wells. In those cases rough stones were from time to time tumbled below the crest of the weir or at the termination of the apron, until experience showed that a sufficient number had been thrown in to counteract the effect of the scour. Another mode was to construct a masonry apron of a greater length, in which upright stones were sometimes placed to 'break' the fall. In some weirs the apron was divided into a series of steps with the same object in view, while in others hollows, or a series of hollows, were constructed in brick or masonry, so that the reservoirs formed should act as a kind of water cushion, and these were occasionally filled with rough stone so as further to break up or distribute the force of the fall.

At that time there was a great divergency of opinion as to the precise forms to be given to weirs. The natives contended that to deal economically and successfully with water, it was only necessary to study the operations of the Great Engineer of the universe, and hence, that the forms adopted for artificial works should as nearly as possible be those by which the desired effects were naturally produced by the action of water. Hence, nearly all their weirs were designed in curves, or a series of curves, in greater or less imitation of the forms assumed when water crossed a natural shoal or hard in the bed of a channel. On the other hand, the Madras Engineer officers for the most part rejected this theory, and adopted straight, level, and perpendicular outlines in their constructions. One of the advantages possessed by the native system was, that the curved surface of the crest of the weir allowed the water to pass over more easily; while the central depression, or depressions, insured a greater degree of uniformity and permanence in the deep-water channels into which the broad beds of sandy rivers with small falls were apt to be divided. Another advantage possessed was, that owing to the greater velocity at the depressed portions of the weir, the sand and silt brought down from the up-country were passed over the weir instead of being allowed to accumulate in the bed of the river on the up-stream side. The practice of the Madras Engineer officers was to construct under-sluices in the body of their weirs in the hope of attaining a like result, but he might safely say that during his experience in the Madras Presidency he had never seen an under-sluice in a weir that had effected the object with which it had been erected, namely, that of keeping the bed of the river above the weir free from accumulations of sand and silt. The under-sluices in the Colleroon Annicuts were a notable illustration of the general correctness of the native views. The under-sluices in both of these works had proved a complete failure, and in the case of the Upper Annicut it had become necessary to revert to the native practice by lowering a portion of the body of the work so as to make a central depression of 700 ft. in width and 2 ft. in depth. He made these special criticisms with less reluctance than he otherwise should have done, because—in their financial and general results—the Colleroon Annicuts had unquestionably proved one of the most remarkable successes on record. None but those who, like himself, had been employed in the district could form an idea of the blessings which they had conferred, or rightly estimate the gratitude and esteem in which the memory of their talented projector, Sir Arthur Cotton, was held by the inhabitants. To the moral energy and persistency of that officer it was mainly due that sanction was obtained for the first large expenditure, under British rule, for irrigation works in India. In these days of facilities of transit and rapid communication of ideas, it was difficult to realise the extent to which the Madras Engineer officers, at that period, had to rely upon their own resources, or the disadvantages consequent upon the comparative isolation from professional intercourse and assistance in which they were placed, and under which they had to discharge their onerous duties.

Colonel Medley, R.E., had seen the Okhla weir while under construction, and certainly had thought it a very bold piece of engineering; but he understood it to be an attempt to apply the Madras system of construction to a stream in Upper India. He understood that system to be a shallow foundation with a long talus of loose stone on the down-stream side, which was repaired and replaced by fresh stone as fast as it was undermined and disturbed by the scour of the river. In Bengal, on the other hand, the foundations were carried to a great depth, often to 60 ft. or 70 ft., until firm soil was reached. The difference in practice he had understood to arise from the presence of stone in the one case and its absence in the other. Bengal Engineers, as a rule, had nothing but brick to work with; but, as there was plenty of stone at Okhla, the Madras practice had been followed.

At Rājghāt, he believed, there was no stone. The mode of construction proposed for the weir at that place seemed hazardous. He should certainly fear a dangerous scouring action at the 'toe' of the down-stream slope.

He had been for four years in charge of the Indus Inundation Canals, of which a slight description might be interesting to the Meeting. They were for the irrigation of what was called the 'khadir,' or bottom-lands of the river, and were simply cuts from the parent stream, generally parallel to its course. They were filled with water when the river was in flood, and emptied again in the cold season, when the river was low. Advantage was then taken of the subsidence of the water to clear out the silt deposits of the channel, in readiness for the next rise. They were thus only useful to the 'khurreef,' or autumn crop, the less valuable of the two; but, owing to the very scanty rainfall of that part of the country, seldom exceeding 4 inches or 5 inches annually, they were of great importance to the cultivators.

As to the perennial canals, which were the more immediate subject of discussion, it had always seemed to him that sufficient attention had not been paid to a better mode of selling the water to the cultivator than the present system of measuring the irrigated land, and charging water-rate by crop and area. He had always thought that the water should be sold, like beer or wine, by measurement, and that any interference with it after it had been delivered at the distributory head was an expensive and meddlesome system, which drew away the engineer from his proper duties, to business which more properly belonged to the revenue authorities. He was quite aware that there were difficulties in the invention or application of a satisfactory module, arising chiefly from the inequality of supply in the main canal, and therefore of the head of pressure at the irrigation outlet, as well as from the want of available fall at this latter point. But he believed those difficulties had been exaggerated, and that any system which gave even a tolerable approximation to fairness would be preferable to the present. In this opinion he was supported by Colonel Fife, the Chief Engineer of Bombay Irrigation, and by other engineers, though he was aware the canal engineers of the North-Western Provinces were generally opposed to it as impracticable.

It also appeared to him that more attention should have been paid to the importance of navigation canals in Upper India, a subject which had only lately received serious attention. He was aware of the great, perhaps the insuperable, difficulty of rendering irrigation canals properly navigable under the conditions that obtained in Northern India; but the importance of cheap water-carriage in a poor country like India, and for bulky articles such as grain, could scarcely be overrated. He did not see the great benefit to be derived from indefinitely increasing the productive agricultural area of a country, unless equal facilities were given for the cheap carriage of the produce. In many countries which are exceedingly productive, the condition of the cultivator was anything but satisfactory. Low wages and low prices, in fact, had always meant poverty all over the world, and always would mean it. He did not undervalue irrigation in saying that it was not the panacea its friends often represented it to be.

He remembered the late Lord Elgin remarking, when he saw the Ganges Canal, that having been in America, he could not help feeling what a pity it was that all the water-power at the various falls should be running to waste. Colonel Medley would like to see the time when English capital, which was expended all over the world, should be applied in that direction, so that great manufactories might be established along that magnificent stream. Meanwhile it was desirable that cheap water communication should be obtained as quickly as possible, so that the whole population of fertile districts should not be employed simply in raising their daily food. With cheap water communication, the failure of the crops would not be the irretrievable misfortune it now was.

Mr. Bruce inquired whether the cross walls of the Okhla weir were founded upon the normal bed of the river, or were sunk below it?

Colonel Medley replied, they were founded upon the normal bed of the river, not sunk.

Mr. Bruce remarked that the ordinary practice in the Madras Presidency would have been to have sunk the wells 6 ft. or 10 ft. below the normal bed of the river, and then to have built the walls upon them.

Colonel Smith said that it was quite true that, as Mr. Bruce mentioned, the Madras practice would have been to sink wells filled with rubble, and to build the walls upon them; but he thought the use of the walls in the Okhla weir was not properly understood. Objection had been made also to there being no foundation to the 'toe' of the dam, both in front and rear. He would point out, with regard to the front of the wall, that a foundation was not found to be necessary, for, instead of the soil being carried away, there was an accumulation, and the whole river-bed gradually filled up, till it reached the crest of the weir. There was, therefore, no occasion for protection to the front wall, or slope. With regard to the rear slope, which was a very long one, it was found that the stones at the end did sink during floods, and as often as they sunk their places were filled up again and again, so that, in the end, a good foundation was secured.

Then, as to the use of the walls. It was found that the great force of the stream in floods often lifted even large stones, and carried them bodily down the slope, so that, if there were nothing to prevent it, the whole of the upper part of the weir would be carried away; consequently, it was found necessary to construct cross walls, to prevent the stones traveling. They were not intended to resist the scour, which was prevented by the front wall and slope.

With respect to the interest upon the capital expended upon the works, Colonel Smith could not vouch for the accuracy of all the statements which might have been put forth, but he remembered on one occasion being permitted to see the accounts of the Ganges Canal, which was unsuccessful for many years, and he was struck with the faithfulness with which every farthing was debited against it. He was happy to learn that the works in the North-Western Provinces paid 6 per cent. upon the capital; but he did not know whether, in making these calculations, the salaries of all the engineers were charged against them or not. He was inclined to believe they were.

With regard to rice irrigation, he himself was a witness that it was not necessarily unhealthy. His son, now present, was born in the midst of it; for at that time Colonel Smith's family occupied a house in the centre of a large area of rice fields, and the same house had been inhabited for years without the least thought of unhealthiness. He believed, if the rice were properly drained, there would be no inconvenience from malaria; certainly neither he nor his family ever suffered from it. If, however, the drainage were neglected, or only half done, the result might be different.

With regard to under-sluices, Mr. Godsman had remarked that "he had never seen an under-sluice in a weir that had effected the object with which it had been erected, namely, that of keeping the bed of the river above the weir free from accumulations of sand and silt." Colonel Smith must, with great deference, say he never now heard of under-sluices which did not answer their purpose. But that was not to keep clear the bed of the river, but the mouth of a supply channel. It was useless to attempt to clear the bed of the river, but it was absolutely necessary to keep the mouth of the irrigation channel clear, and that was done by the under-sluices.

A remark was made about the works of the Grand Annicut having been in existence 1,600 years; and what a lesson it afforded, compared with the works of modern engineers. It was true that the Grand Annicut continues to this day, but the authors of it never considered the question of pounds, shillings, and pence, and it is all the more creditable to modern engineers whose works endured, in which that very important consideration had been attended to. When Sir Arthur Cotton, who was the founder of the modern system of irrigation in Southern India, first went there, it was to repair the defects in the Grand Annicut; and, in doing that, he originated the system which was the glory of Southern India, and a benefit to the whole empire.

Then, something was said about time and height. He believed one of Sir Arthur Cotton's suggestions led to a considerable change in the previous system. In the early days of irrigation, the native plan was to make a channel at such a height in the bank of the river that, when the river rose to that height, the channel was filled, and, when the river went down, the tanks were left full; but it must be observed that sometimes the river never rose to that height, and then the tanks were not filled. That was the defect of the native system. By Sir Arthur Cotton's plan the dam raised the bed of the river, and adjusted the level of the flood to that of the channels, so that they were always filled. That was the difference between the ancient and modern systems, and he thought the latter had the best of it.

With reference to the measurement of water—the Government of India had expressed a desire to have the means of measuring water on a large scale by an apparatus which would be simple and easy of management. He was glad to say there was already a simple method of doing it. An instrument made for another purpose had been accidentally found to possess the property of delivering equal quantities of water in equal times, under any head, and thereby of measuring the quantity of water passing through it. The instrument was very simple, cheap, inaccessible, and, when properly fixed, not liable to get out of order.

Mr. Godsman said, that whatever differences of opinion there might be as regarded the efficacy of the under-sluices, it was desirable that those studying Indian irrigation should clearly understand that they were originally placed in the Colleroon Annicuts with the object of keeping the bed of the river above them free from accumulations of sand and silt. As the contrary might have been inferred from Colonel J. T. Smith's remarks, he would take the liberty of reading some extracts from the Transactions of the Madras Engineers, of which that officer was the editor. In a

Report on the Colleroon Annicuts, Colonel Duncan Sim, the Inspector-General of Irrigation Works, said:—"There remains another objection to be considered which I have not heard stated, but which appears to me to be of more weight than any of the preceding. It is the difficulty to be apprehended in preventing the bed of the Colleroon above the annicut from being raised to a level with the top of the work, or nearly so, by the sand and mud in its passage down the river. If this should happen, it is manifest that the bed of the Colleroon being raised at the point of separation several feet higher than that of the Cauvery, a much larger portion of the mud and sand will be carried into the latter river than can be discharged by the under-sluices or into the sea through the mouth of the river. The object of the annicut is to raise the water, preserving the bed of the river at its present level; for if the bed is raised, the remedy, like all former expedients, will be temporary.[1] . . . . To prevent this evil, a certain number of under-sluices have been constructed in the annicuts, but these are apparently not of sufficient power, for the bed of the Colleroon at both annicuts has already been very considerably raised."[2] And, again, in a subsequent portion of the Report, reverting to the subject, he said:—"In considering in a preceding part of this Paper the objections which have been urged against the annicuts, I have adverted to the difficulty of the gradual deposition above it of the mud and sand brought down by the river in its gushes, and the ruinous consequence which would follow any considerable rise in the bed of the point of separation from its sister stream. The evil was not overlooked by Captain Cotton, who provided for its prevention seven sluices, as already described, distributed along the annicut, having in all twenty-two vents, each about 2 feet in width and 2½ feet in height. But these are evidently inadequate to the purpose, and are far from being sufficiently powerful to regulate the bed of a river 750 yards wide, having a rapid stream 12 or 14 feet deep in high floods. On such a volume of water, bringing down a large quantity of earthy matter from the mountains, twenty-two small openings can scarcely be expected to exercise sufficient influence. The nature of the deposits also increase greatly the difficulty of their removal. They do not consist entirely of sand or gravel, but contain a considerable portion of fine clay and soil, which, as it dries, hardens and forms, with the sand, a mass almost impervious to water, and requiring the influ-

[1] *Vide* Transactions of the Madras Engineers, vol. i., p. 142.
[2] Ibid., p. 143.

ence of an extensive and rapid stream to displace it. The accumulations above both are already very considerable, and in some parts not far below the top of the works."[1]

In his Report on the Irrigation of Southern India, Colonel Baird Smith had also stated that there were twenty openings or sluices in the Upper Annicut, and that the object with which they were constructed was "to effect the passage of the sand, and, if possible, to prevent the bed of the Colleroon above the dam being raised by deposits."[2] And he further stated that they had proved ineffectual, and that, at the time of his visit, the bed of the river above the dam was on the same general level as the crown of the work.[3]

As regarded the question of navigation, it might be interesting to know, that in the Madras Presidency it was the custom to bring the produce from the upper country down the rivers, irrigation channels and canals in wicker boats covered with hides—the down-stream favouring their voyage—and that, when discharged of their load, they were taken to pieces, and carried back by bullocks. He did not consider rice cultivation was necessarily unhealthy if proper precautions were taken as regarded the drainage; but in all tropical and semi-tropical countries he had found that when the water first entered the dry channels, and moistened and stirred up the decayed vegetable matter, a certain amount of endemic disease was inevitable.

Colonel Smith said, that he had expressed a different opinion from Mr. Godsman on one point, which he still maintained. He said that under-sluices in an annicut were not now made to maintain the bed of the river, but only to keep clear the mouth of a supply channel. Colonel Baird Smith himself stated that the under-sluices in the annicut referred to were useless to keep clear the bed of the river.

With regard to the Colleroon, he said it occupied the same position in regard to the Cauvery as a main river does to a supply channel, and the object of the under-sluices in the bank of the Cauvery was to discharge any surplus water from that river into the Colleroon, which was at a lower level; but it was found that there was no means of regulating the bed of the Cauvery except by the construction of a demi-annicut, or wall, across its mouth at the point of separation. What he stated was that the object of under-sluices was, not to keep the bed of the river clear, but only to keep clear the mouth of the side channel, which was the channel for leading off the water for irrigation.

[1] *Vide* Transactions of the Madras Engineers, vol. i., p. 144.
[2] *Vide* "Irrigation in Southern India," p. 18.
[3] Ibid., p. 20.

Mr. Russel Aitken expressed his concurrence with the views of Colonel Medley as to the desirability of selling water for irrigation by actual measurement of the water supplied, but thought there were many difficulties in the way of doing it, as the Hindoo cultivators were very cunning in seeking means for evading payment. He was the only engineer in India who had sold water for irrigation by meter, and it was impossible to conceive the innumerable methods that were practised to evade payment for all the water consumed. Therefore any means invented for measuring water must be exceedingly simple, and at the same time incapable of being tampered with.

The proposed mode of constructing the weir at Rājghāt was quite different from what was originally proposed by Captain Jeffreys; and looking at the construction generally, and the mode in which it was proposed to put in the tail slope, he did not think it practicable to make a permanent work in the manner described. As the level of the water in the river was much higher than the country on one side of it, the danger of causing the river to take a fresh course must not be overlooked.

Mr. Hawksley, President, regretted that the Author was unable to attend to reply upon the discussion. The Paper was really a valuable one. If time had permitted he would, on behalf of the Author, have made a few observations upon some of the principal points which had been discussed; but the hour for adjournment had arrived, and therefore he had not the opportunity of doing the Author that justice which otherwise he should have felt himself obliged to do on the occasion of his enforced absence.

January 21, 1873.

T. HAWKSLEY, President,
in the Chair.

The discussion upon the Paper, No. 1,350, "On the Practice and Results of Irrigation in Northern India," by Colonel W. H. Greathed, was continued throughout the evening, to the exclusion of any other subject.

January 28, 1873.

T. HAWKSLEY, President,
in the Chair.

No. 1,356.—"Cylindrical or Columnar Foundations in Concrete, Brickwork and Stonework." By John Milroy, Assoc. Inst. C.E.[1]

The use of iron cylinders, or caissons for foundations of all kinds, has now become so general as to have apparently excluded, in this country at least, their prototypes, the brick wells of India. Nor is this to be wondered at; for the ease with which they can be handled and put together, the sharp-cutting edge which they present for the penetration of the ground, and their adaptability to what has been till recently, and still is with many, the popular mode of sinking, have naturally rendered their adoption the favourite expedient of the engineer. But the high price iron has now reached, and the invention of improved apparatus for sinking, render this a suitable moment for considering whether iron cylinders are really, in all respects, the best that can be procured, and whether an efficient and economical, and therefore preferable, substitute may not be found in concrete, brick, or stone. The object of the present Paper is to describe an attempt by the Author, acting partly in concert with Mr. J. W. Butler, Assoc. Inst. C.E., to render these materials more easily available for cylindrical foundations.

Brick cylinders demand prior consideration on the ground of their antiquity. It is well known that they have been in use in India for centuries.[2] Their introduction into this country has more than once been suggested, and there is reason to believe that this suggestion has already to some extent been acted on; but probably the Engineers for the Trustees of the Clyde Navigation have been the first to adopt them on a large scale in connection with a great and important work.

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[1] The discussion upon this Paper extended over portions of two evenings, but an abstract of the whole is given consecutively.

[2] *Vide* Minutes of Proceedings Inst. C.E., vol. ii. (1842), p. 63; xvi., p. 449 *et seq.*, and xxviii., p. 325.

The expanding commerce of Glasgow and corresponding growth in the shipping trade have for some time rendered an extension of quay and dock accommodation absolutely necessary. The number of vessels entering the harbour has progressed in a growing ratio; and a range of ships, two or three deep, along the line of wharves, is a common sight during a great part of the year. The inconvenience and delay thus occasioned became at length so unbearable, that in 1869, the Trustees of the Clyde Navigation requested Mr. J. F. Bateman, M. Inst. C.E., and Mr. J. Deas, M. Inst. C.E., to consider and report on the best means for providing a large and progressive extension of quayage, suited to the present and future requirements of the port. Their attention was particularly directed to the necessity of obtaining a greater depth of water in the harbour for the accommodation of ships of the heaviest burden. This result was one not easily attained in the deep stratum of running sand which constitutes the bed and banks of the River Clyde. Hitherto, the quays have been constructed with ordinary retaining walls, founded by means of coffer-dams on piles driven into the sand. This system, besides being deficient in strength and durability, is open to the objection that the foundations cannot easily be carried down so far as to admit of the bed of the river being dredged to the depth required by the largest vessels of the present day. Mr. Bateman and Mr. Deas accordingly directed their attention to iron cylinders, and subsequently, on the suggestion of the Author, to brick cylinders, which seemed to him to be admirably adapted to overcome, economically and effectually, the difficulties of the situation. After due consideration, they presented to the Clyde Trustees an exhaustive report; and in the year 1870, an arrangement was made with the Author, in conjunction with the late Mr. Thomas Brassey, Assoc. Inst. C.E., to construct in brick cylinders, to some extent as an experimental work, the Plantation Quay, an extension westward of the wharves on the south side of the Clyde.

A detailed description of this and similar works, executed, or contemplated by the Clyde Trustees for the improvement of the harbour of Glasgow, might be interesting; but the Author abstains from anticipating any one to whom it might more naturally fall to bring them under the notice of the Institution. Accordingly, after a brief introductory description of the Plantation Quay, he will confine his remarks to the novel manner of making brick cylinders, to the mode of sinking them, to the form of the 'shoe,' and to the general arrangements adopted in the execution of the work.

The Plantation Quay is founded on a hundred brick cylinders, sunk in a continuous line close together, so as to form a length of 400 yards of quay. The wells are 12 ft. in external diameter and 2 ft. 4 in. thick, thus having an internal diameter of 7 ft. 4 in. Their shape is circular, except at the points of contact, where they are formed with 'a tongue and a groove,' that is with a square projection on one side and a corresponding recess on the opposite side, alternately fitting into and sliding down the adjoining wells (Plate 7, Fig. 1). The cylinders thus form a continuous wall, and the ground behind is protected from the disturbing action of the tides. This arrangement was suggested by Mr. Randolph, Chairman of the Works Committee, in place of the wrought-iron tongue which was originally proposed.

The site of the new quay was a sloping bank, pitched with stones, which projected into the river somewhat beyond the line of the cylinders. A trench could accordingly be cut down, preparatory to the sinking, nearly to the level of low water, leaving between it and the river a ridge, which, though not adequate to exclude the tide altogether, was sufficient to prevent the influx of water becoming inconvenient. The depth of water outside was about 14 ft. at the ebb, and the rise of the tide averaged about 8 ft. From the bottom of the trench the cylinders were sunk on the average about 36 ft.; but the earth on the river-side was removed when the sinking was completed, and dredged to a depth of 20 ft. below low water, thus leaving about 14 ft. of cylinder beneath the dredged bed of the river. The cylinders were only carried 2 ft. above low-water mark, and were then—in accordance with a suggestion made by Mr. Bateman for the purpose of saving expense—firmly re-filled with the sand and other materials which had been excavated; a plug of concrete, however, was first lowered through the water in discharging boxes to the bottom of the cylinder to give it a proper bearing, and to protect the rest of the filling from any disturbing influence. In order to obtain a better footing for the superstructure, a strong iron ledge or lintel was laid from cylinder to cylinder over the bays left on the river-side of the points of contact; on the land-side a narrower lintel of stone was laid; and, to secure greater strength, as well as to receive the shock of heavy vessels, an iron girder was fixed across the centre of the cylinder from wall to wall at right angles to the line of the quay. On these foundations, namely, the walls of the cylinders, the lintels, and the cross girders, an ordinary retaining wall was built up, 11 ft. thick at the base, hollow over the spaces in the cylinders between the walls and the girders.

The 'shoe,' or 'curb,' as it is also called, is the circular platform, tapering downwards to a cutting edge, on which the brick well or cylinder rests. The Indian shoe, frequently made of wood by the natives, but generally of iron by British engineers, was the form originally specified. It is a flat annular plate, at least equal to the well in breadth and diameter, from which project downwards an outer vertical iron shell, and an inner shell sloping towards the outer one until they meet, thus enclosing a circular wedge-shaped space. The objection to this shoe is that it wastes iron, and is correspondingly expensive. It is likewise so blunt as to present considerable resistance to sinking through firm and tenacious strata. The Author accordingly devised the shoe shown on Plate 7, Fig. 8. It is a cylindrical iron shell, or short length of iron cylinder, about 4 ft. 6 in. deep, surmounted by an annular plate which is also supported on radial brackets, or feather plates. The annular plate was about 1 ft. 6 in. in breadth, and the bottom courses of brickwork, which were bolted to the plate, were corbelled until the full breadth of the wall was attained. This shoe, besides being less expensive, worked satisfactorily; but from the experience obtained at the Plantation Quay, the Author is of opinion that the amount of iron might frequently be further reduced, in sinking through soft ground, by dispensing with the slight advantage of a sharp cutting edge. It is easy, for light soils, to mould a wedge-shaped ring of concrete, which need be shod only at the edge; nor would it be a bold or hazardous undertaking to sink such a ring without any sheathing at all, if the only obstruction to be encountered was sand.

In India, it is the custom to plant the shoe 'in situ' at the level of the water, and to build on it, brick by brick, a length of cylinder, which is then partially sunk; the workmen next build up a fresh length, brick by brick, and so building and sinking go on alternately until the whole of the well has been sunk. This process is simple, requires little plant, and when the number of cylinders is small, or when they are isolated, or when time is no object, it might be adopted for brick cylinders. But as the Clyde Trustees were desirous that the Plantation Quay should be executed with the utmost despatch, the Author determined to pursue the novel course of constructing the brick cylinders in rings, in frames placed on a platform near the line of the quay, and then to put them together 'in situ' after they had been allowed to consolidate.

The general arrangements necessary to carry out this plan, with a view to the most expeditious removal of shoes, cylinders, weights and apparatus, consisted in the erection in the line of the cylinders of a gauntry of 50 ft. span, with a steam traveler sufficiently high to allow light traveling platforms, carrying the excavating apparatus, to pass underneath. Close at hand a wooden platform was laid down, similar to those on which centres are made, with a low gauntry carrying an overhead steam traveler. On this platform the rings, or annular sections of brick cylinder, were moulded in frames of suitable size, constructed of wood, in four sections, bolted together. The woodwork consisted of two or three ribs, each of three thicknesses of $1\frac{1}{2}$-in. planking, formed to the circle, nailed together, and lined with 1-in. boarding. They were shaped with a recess on one side, and a projection on the other, to form the tongue and groove already spoken of. Annular layers of wood of the shape of the rings were fixed down to the platform, in order that their outer edges might keep the frames in place; while their inner edges served as guides in shaping the eye of the rings in building up the bricks. Four holes, $4\frac{1}{2}$ inches square, were formed in the heart of each ring at equal intervals by means of mandrils set in sockets in the platform, for the purpose of cementing and jointing the rings together. When a frame had been fixed in place, bricklayers proceeded to build up the ring inside with bricks and Portland cement, using the cement freely so as to produce a smooth coating on the outer surface of the cylinder, to reduce the friction in sinking as much as possible. Each ring consumed nearly 2,000 bricks: they were of the ordinary instead of the radiated shape, which, had time permitted, would have been preferred as effecting a saving in cement. The cement, with a view to strength and quick setting, was mixed in the proportion of 1 of cement to 1 of sand. When the brickwork had partially set, the screw bolts which secured the sections of the frame together were unfastened, and the sections removed. The ring was allowed to stand at least five days to consolidate thoroughly, and it could then be moved either to be fixed in place, or to be stored up for future use. It was 2 ft. 6 in. high, and weighed between 9 tons and 10 tons. About 1,200 rings, or about 3,000 lineal feet of brick cylinder were manufactured in this way, being about 8,000 cubic yards, or about 11,000 tons of brickwork. Though only fourteen frames were used in moulding this mass, they kept their shape to the last, and were otherwise perfectly serviceable at the completion of the work. The removal of the rings was effected by means of the small traveler commanding the frame platform, which deposited them on a lorry; the lorry ran on rails up to the line of the cylinders where the large traveler placed them in position. An instrument was specially contrived for lifting them (Plate 7, Figs. 9, 10, 11, and 12). It consists of a three-armed frame, having levers jointed to the outer ends of the arms, and connected by three chains to a hoisting chain: these connecting chains are of such length that when lifting force is applied, the strain tends to draw in the upper ends of the levers and to force out their lower ends. The lower ends are shaped to catch in cavities formed for the purpose in the bottom edge of the eye of the ring; so that when the ring is being lifted, the strain acts as before explained, and prevents the levers being loosened or displaced. When the ring has been lowered, the chains are slackened, the lower ends of the levers are drawn in, and the instrument is removed.

To prepare for sinking, the first thing to be done was to plant the shoe carefully 'in situ,' and to build up the first tier of brickwork, which was bolted to the shoe (Fig. 8). This tier was about 2 ft. 6 in. high, and was splayed out inside from the breadth of the shoe until the full thickness of 2 ft. 4 in. was attained. Rings were then added, and were cemented together and to the bottom tier in the following manner: three thin pieces of boarding were placed at intervals on the lower brickwork, and on them the fresh ring was lowered and carefully adjusted; the joint was pointed all round outside and inside with cement mortar, and, so soon as the pointing had set sufficiently, cement grout was poured into the mandril holes, and well rammed down with a plunger so as to spread and thoroughly fill the spaces between the rings. Bricks were also inserted down the mandril holes to act as dowels between the rings, and prevent them moving on each other.

The sinking of the cylinders or columns thus constructed was effected by means of the Milroy excavator (Fig. 8), a description of which has already been read before the Institution.[1] In order, however, to render this Paper complete, it may be briefly described as a horizontal frame of iron with an outside rim, to which are hinged a number of heavy spades. These spades, when drawn in, come together and form a tray. The various movements are effected by means of two sets of chains attached to the main or hoisting chain; the first set are fastened to the rim of the excavator, and, when looped up on a monkey hook, serve to lower the machines through the water into the ground with the spades open; the second set are each fastened at one end to a spade and

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xxviii., p. 339.

at the other to the end of the hoisting chain. When the machine has been lowered with the spades open, the monkey hook is disengaged: when the engine begins to pull in the hoisting chain, the second set of chains being now the shorter, come into play, drag in the spades through the ground, and raise the whole machine full of earth to the landing-stage to be discharged. To keep the excavator down while the spades are being drawn in, and also to assist in forcing them into the ground, two chains, called holding-down chains, one fastened to either side of the excavator, pass under pulleys bolted to the shoe, up to capstans fixed on the landing-stage.

The only novelty in the use of the excavator at the Plantation Quay consisted in the disposal of the small steam engine and other apparatus for working it, as well as of the lorry for receiving the earth discharged, on small traveling platforms running under the great steam traveler. This arrangement (Plate 7, Fig. 13), was of course special, but was justified by the magnitude of the work, and the speed with which it was desirable to carry it on. A steam pipe being laid along the side of the staging, steam could be obtained at any point: so that, as soon as a cylinder was sunk as far as was possible at the time, the holding-down chains were thrown off, and the platform at once moved out of the way, for the addition of fresh rings to another cylinder, where the apparatus might be in full operation again in a short time. Another novelty was the provision made for taking power from the engine to wind or unwind the holding-down chains, which had formerly been worked entirely by hand. When the spades were in the ground, the attendants threw their weight on the capstans, and held on until they felt that the excavator was rising; at other times, by means of the handles, they could bring in the aid of the engine to wind in the chains by throwing the drums into gear.

The ground through which the cylinders were sunk differed materially from what had been expected. The borings disclosed nothing but sand; but, having been directed rather aside from the line of the cylinders, they failed to show other obstacles which seriously retarded the process of sinking. The first three cylinders were impeded by old piles and fenders connected with the coffer-dam for the adjoining quay, and by tie-rods, which had to be cut by a diver; about a dozen cylinders in the centre of the line encountered a bed of rotten sandstone from 2 ft. to 7 ft. thick, which, fortunately, dipped until it entirely disappeared; whinstone and freestone boulders were frequently met with, and a nest of these troublesome hindrances had to be brought up in sinking the last ten cylinders. The whole of the sinking, however, was effected by means of the excavator, though many of the boulders were of large size, measuring about 3 ft. by 2 ft. 6 in. To raise these obstacles is an operation plainly within the range of its capabilities—the spades seizing any object which they can embrace, or which is rugged enough to afford them sufficient hold. Freestone boulders, being more rugged and friable than whinstone, were more readily grasped. It sometimes happened that the boulder lay in such a position that a spade coming down on it prevented the others from acting; when this became apparent, one or two spades were removed, and thus, after a few attempts, it was always caught in the intermediate space and brought up. The excavator also gnawed its way through the stratum of rock already mentioned.

The difficulty of sinking was materially increased, not only by the close proximity of the cylinders, but also probably by the tongue and groove, the cylinders being thus so interlocked that the slightest divergence from the perpendicular retarded the sinking. Such divergence was unavoidable, as the excavation in one cylinder affected its neighbours to an appreciable extent. Notwithstanding these drawbacks, the whole of the one hundred cylinders were sunk between the month of August, 1870, and January, 1872, or in about seventeen months. But from that period a large deduction should be made for those occasions on which the sinking was, from various causes, wholly or partially suspended. The rate of sinking was very variable: there were days when, with three excavators, as much as 40 ft. were sunk in ten hours; there were also days exceptionally bad, when only 6 ft. were recorded. A fair average per cylinder would be about 4 ft. per day; had the cylinders been isolated, the average rate would have been at least doubled.

The causes already explained rendered heavy weighting necessary. Farther up the river, the Author had sunk isolated iron cylinders 80 ft. through sand, with a load amounting to 2 cwt. per superficial foot of lateral friction. Had the brick wells also been isolated, and had the bed of the river consisted solely of sand, it was calculated that, with the aid perhaps of spare brick rings, they would have required little or no assistance from loading. Under the circumstances, however, a load of 7 cwt. per superficial foot of lateral friction was really required; and to provide for this load, 900 tons of cast-iron weights were kept on the ground. The item of weight was thus a very serious one, entailing an outlay of about £20 per cylinder. For the sake of the advantages gained in loading and unloading, as well as in excavating, the Author again resorted to the system of casting the weights in a form suited to the cylinders. It was not possible to pack them inside, as was done in the iron cylinders of the Clyde Bridge. They were accordingly cast in circular rings of the same diameter and breadth as the brick wells (Plate 7, Fig. 13, A.) They were limited to a thickness of 5 in., that they might afterwards be the more easily broken up. They weighed about 5 tons each, and thus a heavy load could be piled up on the brickwork in a small space, and at the same time there was no risk of the load tilting the cylinder by unequal distribution, as is often the case when rails or pig iron are used. Further, they in no way interfered with the working of the excavating apparatus, and could quickly and easily be moved from cylinder to cylinder. These advantages were not too dearly bought by the outlay in special casting, at least in the opinion of the Author, who has always been strongly impressed by the expediency of such arrangements as will distribute the weight equally, and admit of its remaining on the cylinder, during the course of the sinking, in so heavy a mass as to force the cylinder in its descent to keep pace with the progress of the excavation.

The weighting was effected in the following manner. After the shoe had been pitched and made ready, as many brick rings were added as could conveniently be placed under the excavating platform; and in most instances these, generally 8 in number, and weighing, together with the shoe, about 85 tons, were sunk as far as possible by their own weight; there was then sufficient room to add all the rest of the brick rings, the weight of which was supplemented by as many iron rings as might be required. The rate of sinking diminished as the cylinder descended, owing probably to accumulations of sand in the grooves, and to the fact that any slight divergence of the cylinders from the perpendicular told more decidedly at the greater depth. Notwithstanding an immense load, a cylinder also sometimes 'hung up' without any obvious cause, and then suddenly went away 'with a run,' occasionally breaking a holding-down chain, and burying the shoe in the sand. On six or eight such occasions a diver was brought from a neighbouring work to replace a chain; but if one of the pulleys bolted to the shoe was broken, a pulley lowered between two leaders was easily substituted. In sinking the last few feet the usual load was 62 iron rings, or about 310 tons, which, with the weight of the shoe and brickwork—120 tons—made 430 tons as the load necessary to overcome lateral and vertical friction. When the resistance was very great, owing to the presence of rock or other obstacles, the load of iron sometimes reached 370 tons.

Such was the system pursued in making and sinking the cylinders of the Plantation Quay. The question may be asked, "Why incur the extra expense of the platform, frames, and traveler involved in this system, when the old plan of building the wells brick by brick 'in situ' would have been more simple and equally efficient?" In reply, some minor advantages may first be mentioned. The use of frames secures straightness and exact uniformity of size, a reduction of the external friction by a smooth surface, and an avoidance of the confusion which would be occasioned in the line of the cylinders by the constant presence of scaffolding and materials, and of bricklayers and other workmen. The chief advantage, however, in having a number of cylinders ready made, is the decided increase in the rate of speed at which such a work as a quay wall can be executed. Construction 'in situ' involves the periodical suspension of sinking operations for a considerable time, generally some days, while a length of fresh cylinder is added brick by brick, and allowed to consolidate; whereas, on the Author's system, an equal length in rings can be put together in about a day, and, as the brickwork is already thoroughly set, sinking may be resumed the following morning with perfect safety. In short, brick cylinders in rings can compete with iron cylinders in respect of the ease and speed with which they can be put together. But it may be objected that a considerable number of cylinders might be kept in hand at once, some being sunk and more being built up. Such a plan is, of course, perfectly feasible if they are isolated; but it was found to be dangerous in the case of a large number of cylinders in line in close proximity; for, as has already been pointed out, the excavation in a cylinder has a tendency to throw the neighbouring cylinders out of the perpendicular. They are in this way liable to become so jammed as to be altogether immovable, or, at least, to require a crushing weight to effect their descent. Accordingly, the course finally preferred at the Plantation Quay was to work steadily ahead with only three cylinders at a time, and also, using three excavators, to carry on the excavation and sinking in all three equally and simultaneously.

Before leaving the subject of brick cylinders, another illustration may be given of their application to overcome a difficulty. In the construction of the Glasgow (City) Union Railway, it was necessary to pass under the Glasgow and Paisley Joint Line at a point where the traffic was constant and heavy. The ground through which the cutting had to be made was of the most treacherous description, consisting of a bed of nearly liquid mud, underlying a station, a bridge, and the junction of two lines. For the temporary support of the joint line, strong longitudinal timbers were laid under the rails and sleepers, but, though carefully supported, they required constant attention and wedging during the progress of the work. The top soil was easily removed; but it appeared so dangerous and difficult to cut into the mud and put in the foundations of the bridge and retaining walls, that the Author, with the sanction of Mr. J. F. Blair, M. Inst. C.E., the Company's Engineer, resolved to use brick cylinders. They were 9 ft. in diameter, and rested on a shoe, which consisted simply of a shell of ordinary sheet iron, $\frac{1}{4}$-in. thick, with a set of brackets riveted inside more than half way up. On these was placed a wooden curb, and on it, owing to the want of room and the small extent of the work, a well was by preference built up brick by brick; it was splayed out to the utmost, so as to secure as much weight as possible, only a man-hole being left, through which the workmen descended, and the excavation was removed. As there was little head-room under the temporary bridge, the weighting there proved a difficulty until the agent on that part of the work thought of wedging the cylinder under the beams which carried the rails above. As trains passed very frequently, and their weight and vibration sent down the cylinder a little each time, by constantly tightening the wedges, the cylinders were easily sunk. Twelve cylinders were sunk in this manner, six on each side, for the bridge walls, and eighteen for the retaining walls, all to the depth of 15 ft., or 4 ft. below formation. They were then filled, shoe and all, with concrete, and on this foundation brick arches were turned from centre to centre to provide a proper footing for the superstructure. By this simple use of cylinders a work was accomplished safely and economically which, owing to the great complication of lines, bridges, and station at that point, might have proved very expensive and dangerous.

Of concrete cylinders, or wells of gravel or broken stone mixed with Portland cement, some remarks may now be offered. In practical construction they differ from brick wells only in this, that they must be made in frames or moulds, whether 'in situ' or on a platform, and that an internal as well as an external frame must be used. Construction on a platform is preferable, for the reasons stated, because 'in situ' not only would the frames be in the way of other cylinders, but it is more difficult to keep them perfectly upright. In choosing between brick and concrete, the question is chiefly one of expense. When the Plantation Quay was started, brick cylinders were the cheaper; but now, they have become dearer, as the price of bricks on the Clyde has been nearly doubled. Accordingly concrete cylinders have been adopted by the engineers of the Clyde Trust for the Stobcross Dock and other works now in course of execution. When their relative cost is equal, concrete is perhaps to be preferred, as bricklayers, an expensive and troublesome class of workmen, can be dispensed with. The process is so simple that it can be carried on, under proper surveillance, with unskilled labour. When the concrete has been mixed by hand, or in a mixer, it is discharged into the frame, care being taken to ram it well down, so that it may be properly consolidated; the conditions attending their construction are otherwise much the same as in the case of brick. The lowest, or wedge-shaped ring, however, can be much more easily formed of concrete in a wedge-shaped frame; and if it is desirable that it should be shod, an edge or sheathing can be inserted in the frame, where it is incorporated with the concrete.

In connection with concrete cylinders, mention may be made of the application, by Mr. J. W. Butler, Assoc. Inst. C.E., of Ransome's artificial stone, called 'apœnite,' on the same system as that employed by the Author. 'Apœnite' is a composition capable of being moulded with the greatest nicety and beauty, and, on becoming thoroughly indurated, of resisting extraordinary pressure. Mr. Butler conceived the idea that this substance was admirably adapted for the construction of cylinders; and accordingly, under an arrangement with Mr. Ransome, in 1871, made and sank at the Hermitage Wharf, on the Thames, some experimental cylinders with complete success. They were 8 ft. diameter, and 9 in. thick. The courses or rings were moulded in frames, and were cemented together with the mixture of which they were composed. These cylinders take a very smooth surface, and, owing to the strength of the composition, may be moulded with thinner walls than perhaps would be adopted in the case of brick and concrete.

From these illustrations it will be evident that by the use of frames or moulds, not only may the old brick well be constructed more quickly and satisfactorily, and concrete and other materials made available for cylindrical foundations, but every variety of form may be produced suited to every variety of construction and of situation. A further extension of the system is suggested by the difficulty experienced in sinking loose cylinders in lines or groups. This difficulty is to a great extent overcome:—

1. By forming combinations of cylinders, incorporated with or moulded into each other, and sinking them together.

2. By so shaping them that a number of combinations can, if necessary, be tied into each other in a simple and efficient manner after they are sunk.

Contiguous cylinders, when constructed at the same time, either brick by brick or in rings, may be very easily united by forming a band of concrete or brickwork to tie them together at the points of contact throughout their entire length. But a much more satisfactory combination may be produced, either with or without frames, by incorporating two, three, or more cylinders, so that their contours overlap each other, as shown in the illustrations given (Plate 7, Figs. 2 to 7). The frame or mould for such an arrangement may be made as large as the intended combination, with cores or inner frames for the eyes of the cells. If a tier, or course, is thus constructed on a platform, and is too heavy for the traveler to lift as a whole, dividing boards are inserted in the frame so as to cut up the mass into sections, which are cemented together in place; the position of the dividing boards should be shifted at every course, so as to 'break joint.' In devising a shoe for such a combination it must be observed that in general only the contour of the figure formed by the combination need be shod; the central mass requires no shoe, but at its lower part ought to be higher than the outer walls, so that the cylinders become, in fact, in the region of the shoe, a single chamber.

This system of monolithic combinations may be applied for the foundations of quay and river walls, of docks and forts, of piers and abutments, or wherever a number of cylinders are to be sunk together to support weight or resist pressure. The illustrations given are confined to quay walls, and to the circular form, which combines the utmost strength with the greatest economy of material. Fig. 2 shows a line of cylinders in combinations of four, with a vertical half-cylinder sunk behind the points of contact and filled with concrete. Fig. 3 shows the same combination with an entire cylinder sunk behind the points of contact, and the intervening space excavated and filled with concrete. The object of the back cylinder is to protect the ground behind from disturbance by closing the joint, and also, by tying back the superstructure, to strengthen the wall by a partial counterfort. To facilitate the excavation of the enclosed space, angle irons may be driven down at the corners as the excavation proceeds to keep out the surrounding earth, and can be gradually withdrawn as the concrete which is lowered in discharging boxes, rises. Figs. 2 and 3 are shown merely as efficient arrangements which do not involve great expense; Figs. 4 and 5 exhibit the effects of combination to the greatest advantage. Fig. 4 is a line of single cylinders in combinations of four in front, strengthened by double counter-forts at the joints, so that altogether each combination comprises six cylinders; Fig. 5 shows two lines of cylinders in combinations of four for a stronger and broader wall. Besides the avoidance of the jamming of loose cylinders, the advantages of both these arrangements are:—

1. The provision made in the space between the combinations not only for closing the joint thoroughly by filling it with concrete, but for rendering that part of the wall as strong as any other.

2. The great increase of strength communicated to the foundation, especially in the way of resisting lateral pressure, both by the combining of the cylinders and by the thorough interlocking of the combinations.

3. The avoidance of the necessity for close sinking of the combinations, which—to diminish friction and to prevent jamming—may even be placed a few inches apart, provision having been made in the concreted space for afterwards closing the joint.

4. A considerable saving of expense.

The principle of combination illustrated was submitted by the Author to the Clyde Trustees, who adopted it, and their plans were modified accordingly. They have, however, preferred for the new works now in course of execution, the combinations shown on Figs. 6 and 7. In these the advantages of the system are to some extent sacrificed; for instance, in Fig. 7, not only is there no cohesion among the combinations, but the security of the unclosed skew-joint depends on the close contact of the cylinders, and thus the difficulties arising from friction and jamming are intensified rather than removed.

In conclusion, the Author will briefly point out the advantages which non-metallic cylinders possess in comparison with iron. That they are applicable to works in this country, and have fallen into unmerited neglect, will probably not be disputed. By proper selection of a shoe suited to the strata to be penetrated, the entering part being made sharper and longer in proportion to the density of the ground, they can be sunk with the same ease as iron cylinders. The first expense also, at present prices, is from 50 per cent. to 75 per cent. in their favour, with this important difference: an iron cylinder is after all nothing but a skin to which a weight-bearing body or lining must be given; whereas brick and concrete wells, of the usual thickness, are themselves capable of sustaining considerable pressure. When the weight of the superstructure is not so great as to render a cemented filling throughout advisable, an excellent foundation may be obtained by lowering a plug of concrete so as to close the bottom, and then filling the well with sand, gravel, or any other suitable material that may be at hand. In short, iron cylinders, besides being dearer in themselves, must, when sunk, receive at least a lining of brickwork or concrete, which, it is evident, can itself be sunk without the costly addition of the metallic skin. These advantages, representing both efficiency and economy, entitle columnar foundations of brick and concrete to more favour in this country than they have hitherto received.

The Paper is illustrated by a series of drawings and diagrams, from which Plate 7 has been compiled.

[Mr. J. F. Bateman, F.R.S.,

Fig. 1

Fig. 2.

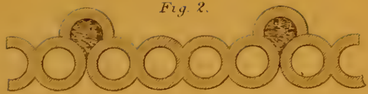


Fig. 3.

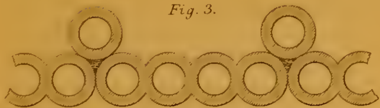


Fig. 4.

Fig. 5.

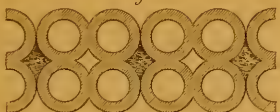


Fig. 6

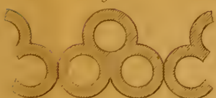
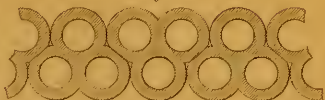


Fig. 7.

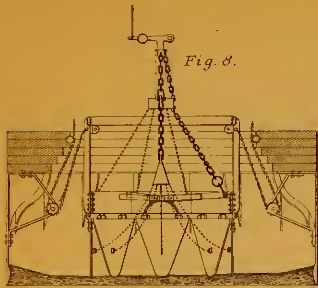


ARRANGEMENT OF CYLINDERS.

Scale for Figs 1 to 7.

Feet 10 5 0 10 20 30 Feet

Fig. 8.



SHOE

Fig. 9.

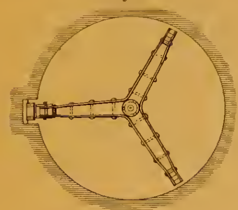


Fig. 10

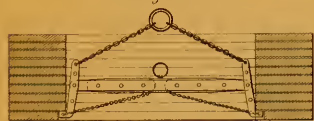
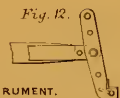


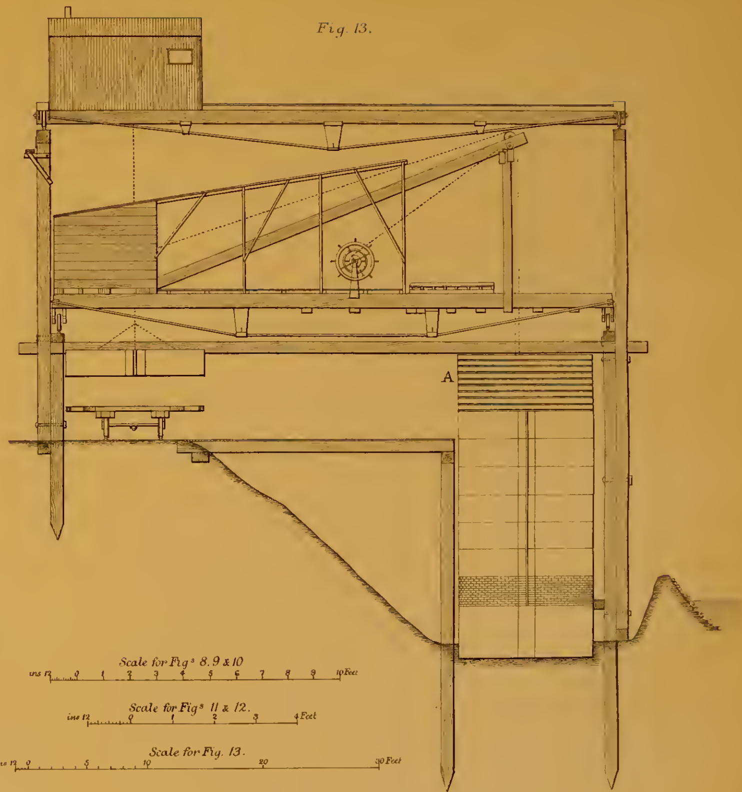
Fig. 11.

Fig. 12.



LIFTING INSTRUMENT.

Fig. 13.



Scale for Figs 8. 9 & 10

ins 12 0 1 2 3 4 5 6 7 8 9 10 Feet

Scale for Figs 11 & 12.

ins 12 0 1 2 3 4 Feet

Scale for Fig. 13.

ins 12 0 5 10 20 30 Feet

ARRANGEMENT OF PLATFORMS.

Mr. J. F. Bateman, F.R.S., said the Paper clearly and ably described the mode of construction adopted in the formation of the Plantation Quay, by the side of the River Clyde, opposite the Broomielaw. As he was the person principally responsible for the introduction of that form of construction he would explain the reasons which had led to its adoption.

For some twenty years before he became officially connected with the Clyde Trustees, there had been docks intended and laid out, and one or two Acts of Parliament were obtained for docks at Stobcross, on the opposite side of the river to that on which the Plantation Quay had been constructed. In co-operation with Mr. J. Deas, M. Inst. C.E., the resident engineer of the Clyde trust, he had laid out works of construction upon this area, including some 4,000 yards of quay wall, besides those for the excavation of tidal basins, called docks. No information existed as to the character of the ground. He knew, from borings in the Clyde, taken with reference to the removal of the old weir above Hutchesontown Bridge, that the bed of the river at that spot consisted of a quicksand 80 ft. deep, of which 30 ft. or 40 ft. had been cleared out by the water falling over the weir. He knew also, by borings taken two years before for the selection of the best place for the construction of graving docks, that lower down the Clyde the ground was a mixture of silt and mud, and sand. He was therefore apprehensive that the ground, in which the Stobcross docks had to be constructed, would consist of the same material, and cause great trouble. It was therefore determined that Mr. Deas should make borings of the whole of the area, which he did, and, when that was done, they met to consider how the work was to be constructed. Mr. Bateman found, as he expected, that the whole area of the ground in which they had to work consisted of various qualities of sand, from coarse to fine—but all quick and water-bearing—with occasional masses of mud and silt, to a depth varying from 25 ft. to 67 ft. below low water. Ordinary modes of construction in such ground were out of the question. To form coffer-dams, within which to build walls, on a quicksand 80 ft. in depth, would probably have failed, and would have been a tedious and expensive work. He then, so far from thinking the ground which they had to deal with was an obstacle to the work, considered it might be turned to advantage; and his first thought was to adopt iron cylinders. But iron cylinders for the purpose of forming quay walls which were to support the ground beyond, especially when that ground was running sand, was a different construction to isolated iron cylinders within a river way, for the purpose of supporting a bridge. Therefore it was necessary to consider how the cylinders could be combined so as to make a continuous wall. He found that for that purpose iron cylinders would be inadmissible, on account of the cost. He then thought of the old Indian system of sinking wells, and whether that principle could be successfully applied under the circumstances they had to deal with. He mentioned this to Mr. Deas, and suggested that Mr. Milroy, who had been employed in sinking iron cylinders for carrying a bridge on the Clyde,[1] immediately above this work, and who had successfully performed that operation by means of the excavator which bears his name, should be consulted, and that gentleman fell in at once with the idea, and spontaneously suggested that brick wells should be used instead of iron cylinders. It was in that way, probably, that Mr. Milroy claimed the merit of suggesting the construction. The result was a general consultation between Mr. Deas, Mr. Milroy, and himself, as to the best mode of performing the operation. Being an experimental work, which would altogether cost some £70,000, there was some probability of a difficulty in inducing the Clyde Trustees to carry out an experiment on so large a scale, but, fortunately for engineering science, they adopted the suggestion. It was desirable to reduce the cost of the experiment to the smallest limit; and as brick cylinders of large diameter, to be united as a continuous wall, had never previously been constructed, they determined—and, he must say, with some little hesitation as to the result—to adopt cylinders of 12 ft. diameter.

The first idea was, to join the cylinders together by leaving hollow grooves on each side, in which to insert a wooden plug, in the same manner as the iron cylinders of the coffer-dams of the Thames Embankment below Westminster Bridge were united. That idea gave way for the adoption of an iron tongue fixed in one cylinder, to be slid down a groove in the other, the object of the tongue being to prevent the possibility of the fine, quick or running sand passing through any openings which might exist between one cylinder and another; and that this difficulty, which it was apprehended might exist, should not cause the failure of the experiment. That junction was afterwards altered to a brick tongue, 16 in. long and 4 in. deep, fitting in a groove of corresponding dimensions in the adjoining cylinder. A little hoop-iron was placed in front of the tongue to reduce rubbing-contact. The cylinders were put down one after

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xxviii., p. 339.

the other, and where no great haste was adopted there was no material difficulty in carrying them down properly and regularly; but many sank unequally in consequence of being unequally weighted.

There were, however, only 2 or 3 out of the 100 cylinders which were not got down to the depth intended, namely, 20 ft. below low water. The depth of water at low water was 20 ft., and the rise of a spring-tide 9 ft. The height of the quay wall above high water was 9 ft., which would make a total height of 38 ft. from the bottom of the river, when it was excavated or dredged to the depth intended, to the top of the quay wall—60 feet was nominally the depth to which the cylinders were to be sunk. The average depth to which they were sunk was only 52 ft. or 53 ft.; and when it was considered that many of these cylinders carried 7 tons to the square foot, before they were sunk to the final depth, upon the ring, 2 ft. 4 in. broad, and that the internal space of 7 ft. 4 in. diameter was afterwards plugged up with concrete, so as to become united with the adjacent ring, capable also of carrying an additional weight, there was no great fear of cylinders so united sinking with any possible weight that could be brought upon them. Therefore, if the question of bearing only were to be considered, the depth to which the cylinders were sunk might have been reduced: but the peculiar character of the soil had also to be considered. Had the depth been shallower, then the weight of the semi-fluid sand behind might have blown up under the cylinder, and let the quay wall down. It was necessary, having reference to that contingency, that the cylinders should be sunk to a considerable depth.

The work was extremely well arranged by Mr. Milroy, who was associated with Mr. Brassey as contractor for the works. There was no lack of energy, capital, or plant. It must be remembered that the iron rings, employed as weights to sink the cylinders, alone cost £4,000 or £5,000, in addition to the other plant necessary for the execution of the work, the gross value of which was about £70,000. This showed the energy and enterprise of the contractors; and everything was done which skill and ample means could accomplish.

The work commenced in August, 1869, and was completed, as to the cylinders, in January, 1871; giving about 16 months, or 17 months, as the time in which the whole length of 400 yards was executed. The cost of the wall, completed, was about £113 per lineal yard; and that, when compared with the cost of any other possible wall, was a cheap construction, though perhaps not much cheaper than an ordinary quay wall in favourable ground. It was a perfectly safe wall; and the only danger, which he from the first apprehended, was that of the sand blowing from behind. It so happened, just as the cylinders were nearly completed, that that danger not only showed itself, but was at one moment a source of anxiety. When four-fifths of the whole of the cylinders were done, he—being in Glasgow at the time—saw a dredger at work in front of the cylinders. The dredger was excavating the sand in front of the wall to the required depth of 20 ft. It seemed there were some old piles left in the river, which the men employed were anxious to get out, and, thinking that the wall was strong enough to bear anything, they dredged to 27 ft., and sent down divers to attach chains to lug out the piles, like pulling out the teeth of a man; in doing which they heard a rushing noise as of falling water, but no other apparent result. Next morning a slight bulge, or variation from a straight line, of about $1\frac{1}{2}$ in. was observed in the wall. On being informed of the occurrence, he concluded that the noise which had been heard was a blow of sand. It was found that the depth, which had been 23 ft., or 24 ft. the day before, was only 17 ft. the next morning, showing undoubtedly that the sand had blown, in the way which he apprehended from the first might possibly occur, and which was the only danger in the construction of the work. The damage, however, was so extremely slight that it in no way impaired the works. It was necessary to guard against this mischief in future; and it was done by constructing very heavy blocks of concrete and brick on the other side of the wharf, 60 ft. or 70 ft. off, and then running tie-rods from the blocks to the front of the cylinders, between every other cylinder. The weight of the blocks was some 3 tons or 4 tons, which added to the expense of the wall £3 or £4 per lineal yard, but that was not a very great addition. He believed the wall so constructed was almost the cheapest form of cylinder construction that could be executed. It was perfectly successful. The sheds had been erected on it, and had been in use eight months or ten months. He had always urged that concrete should be used, believing it was cheaper and better for the purpose than bricks, but Mr. Milroy preferred to use bricks in cement. Mr. Bateman had previously had considerable experience in building sea walls in concrete, composed of Portland cement, and beach shingle, the cost of which was about 12*s.* per cubic yard. In the case of the harbour works at Dublin, as to which he was consulted by the Ballast Board, Mr. Stoney, M. Inst. C.E., built blocks of 350 tons, with a granite ashlar facing, in Portland cement concrete, at a total cost of 16*s.* 6*d.* per cubic yard. Mr. Bateman having that experience present to his mind, was anxious to have concrete in preference to bricks. Mr. Milroy, although he preferred brick at that time, now appeared to consider that concrete in Portland cement was the best material for this construction.

After the completion of a portion of the work, the necessity arose for considering how the remainder should be carried out; there being 4,000 yards more of quay wall to construct in similar ground. The slight accident that occurred was of value, showing the danger they had to guard against; and a minute account was kept of every occurrence that could possibly bear upon the subject, and every detail of the work was as well known to those who superintended it, as it was to the contractor himself. A variety of suggestions were made as to the best form of construction for the remainder of the work; Mr. Milroy considered that 2, 3, or 4 cylinders might be sunk together, of the diameter of 12 ft. each, the spaces between being filled with concrete to prevent the sand blowing a passage through; and his favourite plan, to which he still adhered, was that shown in Figs. 4 and 5, the latter especially, in which four cylinders, forming a square, were to be sunk together, and the intermediate space between that group and the next group of four cylinders plugged up with concrete. There would have been some difficulty in extracting the sand in this space, and in filling the space or pocket with concrete to the depth necessary to prevent its further passage. Mr. Bateman might mention that on two or three occasions, where the cylinders were nearly down to full depth, the sand suddenly rushed up from the bottom, flowing out of the top of the cylinder. There would have been the same danger again that the sand would have blown from the inside to the outside, from the probable difficulty of completely filling the intermediate space with concrete. Mr. Deas turned his attention to every detail, for the purpose of preventing the passage of sand in this particular way, or under the cylinders, or through the joints. The plan finally determined upon, and on which fresh contracts had been made for the remaining portion of the work, was that shown in Fig. 7; namely, in groups of three cylinders: two in front and one behind; and one in front and two behind, alternately. The small spaces in the middle were the only places where any sand could accumulate between cylinder and cylinder; and the sand passing from behind to the front must pass from behind through a joint to the first small space, and from thence through a second joint to the other small space, and then through a third joint. It thus had three joints to pass through, and two of those intermediate small spaces or pockets, all of which might be filled either with wooden plugs or iron piles, after the sand was withdrawn. Although Mr. Milroy deprecated the plan which had been adopted, as incurring a greater amount of friction during the operation of sinking than would be incurred by the sinking of four cylinders together, it must be remembered that by sinking three cylinders instead of four, the work would probably be more easily accomplished. The only difference was the increased rubbing surface on the groups of three cylinders alternately, which for some distance would be not touching only, but in pretty close contact, for the sides had to be cut off for some distance, in order to make the groups fit in properly. This plan was still in course of trial. If the work was accomplished in the way in which it was designed, it would be a more solid construction than if groups of four cylinders had been employed, inasmuch as it would more effectually prevent the passage of sand. It also gave a broad base of nearly 18 ft. for the subsequent erection of the superstructure of the wall, which would be built in the ordinary way of ashlar face and rubble stone backing. This plan, he believed, would be carried out with tolerable facility. He would conclude with one word of caution. This construction of wall was not suited to any ground which was not mud or sand; in stiff ground it would be of no use; nor was it a suitable construction for rough gravel with boulders; but in quicksand, or soft mud, he believed it was the most suitable and economical construction that could be adopted.

Mr. C. B. Lane could not concur in the opinion that brick cylinders were only suitable for foundations in sand or mud. It appeared to him that the system was applicable to other engineering constructions where large vertical cylindrical spaces were required below the surface of the ground. It was nearly fifty years ago since the sinking of brick cylinders was adopted in England on a scale, perhaps, the largest ever known in the world. He alluded to the brick cylinders which had been sunk by Sir Isambard Brunel, in the year 1823, on the opposite sides of the river, preparatory to the construction of the Thames Tunnel. The Author deserved the thanks of the Institution for bringing before it a record of successful application of the system to the peculiar conditions involved in the construction of the Plantation Quay.

Mr. W. Crouch said, the point brought forward as one of novelty in this application was the building of the cylinders in rings, and so applying them that they could be more conveniently used than upon the old plan of building them up gradually as they sank down. He noticed this while the Plantation Quay was in progress, and was satisfied that the method adopted possessed considerable advantages over the old plan in rapidity of construction.

As regarded the arrangement of the cylinders, he considered that indicated by Figs. 4 and 5 to be superior to that shown by Figs. 6 and 7. In sinking, it was not easy to get the cylinders quite uniform or in close contact; and the difficulty in the case of the Clyde was that the sand and other fine materials were apt to find their way through any small apertures at the junction of the cylinders. Figs. 4 and 5 appeared to have this advantage, that the spaces left by those arrangements of the points of contact of the groups of cylinders could be cleaned out, after the sinking was completed, and filled in with concrete, which would have the effect of preventing any run of sand or other fine material between them from the back of the wall. He had the opportunity of seeing Mr. Milroy's apparatus at work, and he regarded it as the most effectual way of sinking cylinders, in sand and light soils where water was met with, that he had hitherto witnessed.

Mr. A. M. Rendel said that he was the Engineer to the works at Hermitage Wharf, which had been alluded to in the Paper. He reported to his directors that iron was not the best material for the cylinders, and that brick should be used instead. He was glad to find that Mr. Milroy was now in favour of brick, but at that time he was very strongly in favour of iron.

Mr. Redman said, the Paper was to a certain extent deficient in illustrative diagrams. If the Author had given a cross-section of the River Clyde where this important work was situated, showing the foreshore behind the work to the natural surface of the ground, there would have been data to form some opinion as to the conditions under which the quay had been constructed. At present the diagrams only showed the appliances for sinking the cylinders.

There was another item of information which the Author had not given, that was the absolute weight upon the cylinders. He should assume that the weight per superficial foot of the cylinders themselves, and the structure standing upon them—excluding the internal diameter because it was filled with sand—was from 2 tons to 3 tons per foot superficial. That was not a great weight upon such foundations. Having had experience in similar work, he was under the impression that where the cylinders could be carried down to a harder stratum below, a modification of this plan might be adopted; and that keeping an intervening space between the cylinders, and closing the front spaces next to the river with sheet piles, the same object of an extended base area might be obtained at comparatively less cost, and the labour of sinking the cylinders would be materially reduced.

The Author stated that the greatest weight required to sink one of the cylinders was 300 tons, and that the frictional resistance was 7 cwt. per square foot of surface. Taking the height of the cylinder by the circumferential surface, the frictional resistance amounted to 3 tons per foot superficial; but that was not due solely to the frictional resistance of the material through which the cylinder was sunk, but to the system adopted of locking the cylinders together as described in the Paper. It would have been interesting to have known what was the resistance of one of these cylinders sunk fairly through the silt. In the case of the wharf described, the resistance 'in situ' afforded by the material in which the cylinders were buried, was due to the front and back surfaces of the block of cylinders alone. In the case of a large cylinder, such as a cylinder supporting the column of a bridge, it was difficult to estimate the absolute weight on the area of the pier, on account of the frictional resistance which acted in supporting the load.

The cast-iron shoe described in the Paper had been adopted successfully in London in sinking artesian wells, and also through the alluvial soil of the valley of the Thames.[1] No better adjunct to the work could be selected; it gave weight to the cutting edge. But it was questionable whether an instrument of this kind was well adapted for sinking cylinders through an almost semi-fluid mass. However much it might assist the cylinder in sinking, it must be, when the work was finished, a dead weight on the cylinder, and to a certain extent reduce its area. In the event of a settlement in such a material, it would aid, rather than retard, such a tendency.

The shafts sunk by the elder Brunel for the Thames Tunnel were 60 ft. diameter.

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[1] Reference may be made to a cast-iron curb which was used by Messrs. Walker and Burgess for sinking a well at Woolwich Dockyard in October, 1839. It was 7 ft. diameter and 1 ft. 6 in. deep, with a rebate outside for planks, and inner bracketted diaphragm for the support of the brickwork of the well. Its weight was 3½ tons. Mr. Townsend, who had charge of the works at Woolwich, writes:—

"*Devonport, February* 16*th*, 1873.

"The curb, when in place, after a few feet of the upper surface had been removed, was sunk simply by excavating within its circumference. The brickwork on its ledge adding to the downward tendency."

J. B. R.

Mr. Frederick Ransome said there were circumstances under which iron was the best material for foundation cylinders. It was a well-known and well-tried material, and was to a certain extent in popular favour; but there were other circumstances wherein iron might not be considered so expedient as brick or 'apœnite.' In many cases where foundation cylinders were proposed to be sunk, there was a certain amount of débris to be removed. This could be used in the construction of 'apœnite' cylinders. In estimating the comparative cost much depended upon the facility with which the material was produced and brought to the works; but, all conditions being equal, he ventured to say that the balance was in favour of such a material as 'apœnite,' the more particularly as that substance could be produced on the spot, lowered into position, and remain there as a permanent part of the structure. In most instances where iron cylinders were used they were to a great extent regarded merely as the shell of that which they were permanently to contain, and when the iron gave way the stone or concrete would remain. 'Apœnite' was employed for the cylinders sunk under the direction of Mr. Rendel at Hermitage Wharf; and although in some cases the 'apœnite' cylinders at the time they were sunk were only three days old, the work had been carried out most successfully. The tests of strength of the material and its power to resist crushing weight showed that, at the age of a month or six weeks, it would sustain a pressure of 4 tons to 5 tons per superficial inch.

Mr. Imrie Bell, through the Secretary, said he considered the increasing use of brick and concrete cylinders for foundations would be attended with a saving of time and expense. He had previously, in 1869, shown that it was a system of construction specially applicable for quay walls, aprons to graving and wet docks, and for engine-seats.[1] While approving of Mr. Milroy's plan of building the brickwork rings, and of fixing them in position, he thought the dimensions of the wells were insufficient for the great height of the superstructure of quay wall, which was 38 ft. above the level of the dredged channel. It would be well that the Author should state whether the counterforts and iron tie-rods, by which the quay wall was strengthened, were included in the original design, or if they were found necessary afterwards to prevent the wall from bulging? He considered it might be preferable to construct the cylinders of different diameters, according to the depth required to be dredged

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xxviii., p. 338.

in front of the wall. It would be easy to arrange for a well or cylinder 15 ft. or 20 ft. diameter for the lower portion, decreasing towards the upper portion, and carrying out the form at the points of contact to suit the square tongue and recess (Fig. 1), so as to bind the whole into one uniform mass or wall. It was also desirable that the Author should place on record the several costs of the cylinders in brickwork and in concrete, together with the proportions of cement in the mortar of the one, and of concrete in the other. Also the cost per foot on an average in sinking, as distinguished from the total cost of sinking the one hundred cylinders. It was only from an average of the total cost of sinking all the cylinders that reliable data could be determined for works of such magnitude. Concrete was used almost entirely in the works connected with the new harbour at St. Helier, Jersey, which Mr. Bell was carrying out under, and from the designs of, Sir John Coode, M. Inst. C.E. The large blocks in this structure weighed about 12 tons each, and they could be lifted and removed three days after making. The completed portion of the sea wall—about 100 yards in length—had withstood intact the storms of the past winter, which had caused so much destruction to many works of a similar character. He considered it likely that concrete, as applied to river or harbour works, would come very generally into use, because the manufacture of Portland cement had attained great perfection. Where gravel or sand was not easily obtained, stone or shingle could be employed. By the appliance of steam power, combined with the use of stone and sand-crushing machines, any necessary amount of material could be manufactured.

Mr. Milroy, through the Secretary, in reply, stated that the object of the Paper was not so much to give a detailed account of the Plantation Quay as to describe his system of constructing non-metallic cylinders in rings and combinations, in connection with an important application of that system in actual practice. Nor did he claim any merit for the suggestion of brick cylinders, a form of construction long established in India for river-wall and other foundations, and well known to every Engineer. There was no record of the use of brick wells in Great Britain—at any rate, for foundations. The two large shafts sunk in connection with the Thames Tunnel were for a different purpose. It, however, by no means followed that they had not been so applied. They certainly had been used many years ago in France for the piers of a bridge. Instances so trifling, however, would not affect the statement in the Paper that the Engineers of the Clyde Navigation had been the first to adopt them in this country "on a large scale;" by which expression he meant to refer, not to the dimensions, but to the number of the cylinders. The works already contemplated on the Clyde might require about two thousand cylinders. With regard to the Hermitage Wharf, to which Mr. Rendel had referred, iron cylinders had been suggested by Mr. Falshaw, one of the directors of the Company, before either Mr. Milroy or Mr. Rendel was consulted; and the suggestion was afterwards adopted, owing to the difficulty anticipated in sinking a blunt brick cylinder, 18 ft. diameter, by excavating machinery, through the Thames gravel, and to the risk of injury apprehended to adjoining buildings if pumping were resorted to. He had no prejudice in favour of any particular kind of cylinder, believing that iron, brick, or concrete should be used according to the requirements of the case; but he was decidedly of opinion that a great deal of money had been wasted by the exclusive use of iron. What he advocated was, that metal, on account of its cost, should not be employed to a greater extent than was absolutely necessary. He ventured to differ from Mr. Bateman's opinion that non-metallic cylinders were only suited for mud or sand. Mr. Milroy conceived that they were equally well adapted to hard, stony ground, provided the shoes were so constructed as to afford free penetration. An iron cylinder certainly possessed one advantage in its thin cutting wall; but that advantage resided entirely at the bottom of the cylinder, and could be secured for the brick well by retaining a length or two of iron cylinder at the bottom, and building thereon brick, concrete, or stonework resting on strong iron brackets. Not only would such an arrangement be more economical, but it provided, to a greater or less extent, the load necessary for weighting. It was worth remarking generally, with regard to non-metallic cylinders, that they required less loading than iron cylinders, and when isolated in soft ground might be sunk, under proper management, without weights. The selection of brick, concrete, or stone for columnar foundations could be determined only by the conveniences or exigencies of the work under consideration: the question resolved itself into one chiefly of expense. Though preferring concrete so long as it was the cheaper form of construction, the Author had, since the Paper was written, advised brick combinations for a work on the Continent where bricks could be more readily obtained than stone. Any information which he could give as to the relative cost of the various kinds of non-metallic cylinders would probably only be misleading, as the cost would vary according to the locality and circumstances of any particular work. With regard to the system of combinations, he adhered to the opinion that the concreted space between, was the most convenient and efficient contrivance for interlocking them. The space could certainly be excavated as easily as the interior of a cylinder, and, when filled with concrete, it secured the advantages claimed for it. He might add that, since the Paper was written, he had sunk a number of combinations of three cylinders each on the Clyde with complete success. In addition to the advantages detailed in the Paper, it was found that by excavating simultaneously in the three openings the workmen had complete control over the mass, so as to be able to sink the combinations evenly, close to each other, and that the amount of weight required to force them down was very much diminished.

The seeming discrepancy between his statement of the weight required to overcome friction, &c., in sinking the cylinders, and the amount estimated by Mr. Redman, must arise from a different mode of calculating or of stating the result. Mr. Milroy took the load, 310 tons, with the weight of the cylinder, 120 tons, and, dividing the sum, 430 tons, by the area of the outside of the cylinder, obtained a result of nearly 7 cwt. for every superficial foot of that area, or per square foot of lateral friction.

February 4, 1873.

T. HAWKSLEY, President,
in the Chair.

The following Candidates were balloted for and duly elected:— John Fowler, Philip Henry MacAdam, Thomas Medcalf, and John Watt Sandeman, as Members; John Baldwin, William Berrell, Stud. Inst. C.E., Henry James Castle, jun., George Coates, James Murray Dobson, Stud. Inst. C.E., Alpin Grant Fowler, Stud. Inst. C.E., Francis William Fox, Charles Cockburn Gibbons, Charles Browne Goldson, M.A., John Gordon, Henry Gruning, Henry Hughes, Henry James Jackson [Jackson Bey], James Verchild Ley, Stud. Inst. C.E., Deodatus Hilin William Johnstoun Nelson O'Neale Neale, Stud. Inst. C.E., James Wallace Peggs, Arthur Frederick Phillips, Robert James Quelch, James Richardson, Alexander Siemens, Stud. Inst. C.E., John Steell, and John Hooper Wait, as Associates.

It was announced that the Council, acting under the provisions of Sect. III., Cl. VII., of the Bye-Laws, had transferred Thomas Robert Winder from the class of Associate to that of Member.

Also, that the following Candidates, having been duly recommended, had been admitted by the Council, under the provisions of Sect. IV. of the Bye-Laws, as Students of the Institution:— George Neill Abernethy, Joseph Samuel Beeman, George William Beynon, Walter Henry Cobley, Charles Henfrey, jun., Thomas Patch, Robert Pickwell, Edward Stanhope Ratcliffe, Frank Stileman, Bernard Francis Wardell, and William Wright.

The discussion upon the Paper, No. 1,356, "Cylindrical or Columnar Foundations in Concrete, Brickwork, and Stonework," by Mr. John Milroy, was resumed and concluded.

No. 1,365.—"The Relative Advantages of the 5 Ft. 6 In. Gauge and of the Mètre Gauge for the State Railways of India, and particularly for those of the Punjâb." By WILLIAM THOMAS THORNTON, C.B., Secretary of the Public Works Department, India Office.[1]

THE one solitary reason of the Indian Government for adopting a narrow gauge was belief in its superior economy. The first thing, therefore, is to determine whether this economy is real or imaginary; for, although it might be real without serving as sufficient justification for the course taken, still, unless it be real, that course remains without any justification at all.

[1] The discussion upon this Paper extended over portions of seven evenings, but an abstract of the whole is given consecutively.

EDITORIAL NOTE.—It is considered desirable specially to draw attention to some material corrections which have been made by the Author and the speakers subsequently to the reading and discussion of this Paper. During the discussion the arguments of several of the speakers were principally addressed to the statement contained in the following paragraph of the Paper:—

"Now the programme of the Indian Government for State railways contemplated the construction in all of about 10,000 miles of such lines. By making them, therefore, on the mètre gauge, instead of on the standard gauge, Government might confidently reckon on a saving of very little, if at all, less than ten millions sterling. It had, as was at the outset admitted, but one solitary reason for its choice between the two gauges; but that reason was of the vast pecuniary weight just mentioned, and will surely henceforth be admitted to be sufficient, unless it can be shown to be counterbalanced by other considerations." [a]

On the 7th of May, 1873, a foot-note was added to the discussion by the Author, in which he says:—

"I am sorry to find myself, on further inquiry, obliged to admit that this was a considerable over-statement. The Indian Government did certainly in March, 1869, represent to the Secretary of State that about 10,000 miles were then wanting, in addition to the 5,000 miles already constructed or in process of construction, to provide India with a complete network of railways, but of those 10,000 miles, not more than 3,000 have as yet been actually marked out.—W. T. T." [b]

[a] *Vide* post, p. 217. [b] *Vide* post, p. 452.

Now that, *cæteris paribus*, a narrow-gauge railway must be cheaper than a broad-gauge railway, would, as an abstract proposition, seem to be also a self-evident one. It may indeed be objected, as it has been by a high authority, that the elements which determine the cost of a railway are the size and the weight of the vehicles to be used upon it, and that it is equally possible with the same gauge to use either broad or narrow, heavy or light vehicles; and doubtless it would be possible, by furnishing a narrow-gauge line with heavy rails and other constituents, and with broad vehicles, to cause the cost to exceed that of a broad gauge with light rails and narrow vehicles. Practically, however, the broad gauge is never adopted except when broad, heavy vehicles, nor the narrow gauge, except when comparatively narrow and light vehicles, are intended to be used; and in any comparison of the two gauges this intention may always fairly be assumed. But on this assumption certain economies, more or less important, will be facilitated by the adoption of a narrow-gauge line.

There will be savings:—

1. In land, represented by a slip of the width of the difference between the two gauges, and of the length of the line of railway.
2. In earthwork, to an extent varying with the depth of the cuttings and the height of the embankments.
3. In the longitudinal and cross girders of bridgework, and also in the timber or iron covering of the same.
4. In sleepers.
5. In ballast.

Supposing the gauges compared, to be those of 3 ft. 6 in. and 5 ft. 6 in., and the weight of the rails to be the same in both, the difference of cost on these five items in favour of the narrower gauge is, by Mr. Hawkshaw, estimated as follows:—

	£	
Land	10	per mile.
Earthwork	100	,,
Bridgework	50	,,
Sleepers, and ballast	200	,,
Total	£360	,,

By Mr. Fowler, who omits to take land into account, the other savings are calculated as follows:—

	£	
Earthwork	37	per mile.
Bridgework	83	,,
Sleepers, ballast, and laying . . .	503	,,
	£623	,,
Or, with addition for land of . . .	10	,,
Total	£633	,,

	£
Taking the mean between these totals, namely	497
And adding, as Mr. Fowler does, for diminished cost of engineering and agency	87
And, as Mr. Hawkshaw does, for saving in maintenance and renewal of permanent way, at £10 per mile, capitalized at 20 years' purchase	200
There is a fresh total of	£784

which may be fairly claimed as representing (according to the average of the judgments of these authorities), the superior cheapness of an Indian railway of 3 ft. 6 in. gauge over one of 5 ft. 6 in. gauge. Mr. Hawkshaw, indeed, considers that a further saving of £200 a mile should be allowed as obtainable by the use of sharper curves; and, as among the State railways contemplated there are some, like the Carwar-Hooblee, Khundwa-Indore, and Lahore-Peshawur lines, traversing exceedingly hilly and even mountainous tracts, the allowance does not seem too great, and, being added to the sum of the previously mentioned items, would bring up the total to £984 a mile.

Another saving of £200 a mile is conceded by Mr. Hawkshaw, under the head of locomotives; but as, although including this in his estimate, he shows apparently conclusive reasons why it ought not to be included, it will here be disregarded, nor will the comparative trifle of £12 per mile, allowed by Mr. Fowler on the same account, be taken credit for.

After all reasonable deductions then, the saving obtainable by the adoption of a 3 ft. 6 in. gauge is, according to the verdict of by no means over-favourable judges, at least £784, if not £984 per mile. But the gauge actually selected by the Indian Government is one of 3 ft. 3 in., or the so-called mètre gauge; and as, according to Mr. Fowler, a reduction of the gauge from 3 ft. 6 in. to 2 ft. 9 in. would, in India, make a difference in cost of £110 per mile, a reduction to 3 ft. 3 in. would, rateably, reduce the cost by nearly £37 per mile, thereby raising the total saving to £821 per mile, or to £1,021 per mile, according as the economy possibly referable to sharper curves be, or be not, taken into account. Perhaps the fairest plan will be to split the difference, and to assume that, as a general rule, a railway in India on the mètre gauge would be cheaper than an equally substantial line on a 5 ft. 6 in. gauge by £921, or, in numbers rounded by the addition of the capitalized value of a further saving on annual repairs, by £1,000 per mile.

Now the programme of the Indian Government for State railways contemplated the construction in all of about 10,000 miles of such lines. By making them, therefore, on the mètre gauge, instead of on the standard gauge, Government might confidently reckon on a saving of very little, if at all, less than ten millions sterling. It had, as was at the outset admitted, but one solitary reason for its choice between the two gauges; but that reason was of the vast pecuniary weight just mentioned, and will surely henceforth be admitted to be sufficient, unless it can be shown to be counterbalanced by other considerations.

It will scarcely be argued that the transport of the utmost amount of traffic to be expected on any of the contemplated lines would be beyond the capacity of the mètre gauge. On the contrary, there are, probably, few who will not admit that, if railway construction in India were now being for the first time introduced, it might be wiser to have all, even of the existing lines, that is to say, all those of the guaranteed companies, either on the mètre gauge, or, at any rate, on some gauge a good deal narrower than the present Indian standard—say, for example, on one of 3 ft. 6 in. If the traffic on the existing guaranteed lines were anything like what it was originally expected to be—were of anything like the amount for which the lines were designed, and on which the original shareholders fondly reckoned—they would surely be yielding much more nearly 10 per cent. than 5 per cent. on their cost. What they are on an average really yielding is, however, less than 3 per cent.; whence it may be safely inferred that their present traffic is certainly not three-fifths, and is most probably not three-tenths, of what, with their actual standard gauge, they could carry; nor, therefore, more, if indeed nearly so much, as they could carry, if their gauge were less by two-fifths than the standard gauge. But, if this narrower gauge would suffice for the traffic of the existing guaranteed lines, of course it would be more than sufficient for that of the projected State lines, which, in a commercial sense, are so much less promising.

A narrow gauge being then plainly sufficient for the State lines, regarded by themselves separately, and without reference to any larger system with which they might be connected, the only objection to the adoption of such a gauge is that of the disadvantages of break of gauge. The extreme gravity of those disadvantages need not as yet be questioned. For the present, and for the sake of argument, they may be admitted to the fullest extent that any one may desire; for, in regard to the immediate issue, there is no place for any argument arising out of them.

The position of the Indian Government, when first conceiving its State railway policy, may be sufficiently understood from what the position is now: to wit, as follows. On about £90,000,000 sterling, expended by railway companies on about 5,000 miles of open railway, it guarantees interest to the extent of £4,500,000 per annum; while the net earnings of all the guaranteed lines, in the last year for which returns have been received, were somewhat less than £2,840,000; leaving £1,660,000 for the Indian tax-payer to make up. On the reasonable supposition that the rates and fares of the guaranteed railways are fixed with a view to the production of the largest possible revenue, their gross earnings may be regarded as representing what the people of India, for whose benefit the railways were made, are willing to pay for such benefits; in other words, what, in their opinion, these benefits are worth. By being made to pay for the said benefits £1,660,000 over and above the amount represented by the gross earnings, they are plainly paying £1,660,000 more than the persons who use the railways, and who ought to be tolerably good judges of that particular point, do believe the said benefits to be worth.

Whether the Indian Government was warranted in forcing railway blessings on its subjects, at a price so far above the market-rate, may be an open question; but there can be no doubt that to such forcing there ought to be a limit. Most assuredly it can be no just ground of reproach against the Government, to have been satisfied with compelling its subjects to pay so exorbitantly for the use of the 5,000 miles of railway already made, and to have determined, with respect to the 10,000 miles remaining to be executed, that they should, if possible, be constructed so cheaply, that the receipts from customers would suffice to pay full interest on their cost, without requiring to be supplemented out of taxes. But, even with all the extra cheapness attendant on the narrow gauge, scarcely any of the projected State lines are expected to be quite cheap enough for this; indeed, were it not that they are expected to be strategically and politically, as well as commercially, useful, scarcely any of them could, consistently with the Government's present sense of duty, have been permitted to be made. But, under such circumstances, for Government to allow the cost of the railways to be increased by ten millions sterling, in order to avoid the evils, however great they might be, of break of gauge, was plainly out of the question. The choice did not lie between narrow-gauge railways and broad-gauge railways, but between narrow-gauge railways and no railways at all; and those who disapprove of such limitation of choice must be prepared to prove that the break of gauge, however bad it may be, is not still an important improvement upon the previously existing break between railways and common roads.

Thus much in regard to the preliminary and more comprehensive question. But, although the narrow gauge may be the more suitable for Indian State railways generally, there may be particular localities for which, owing to particular circumstances, the broad gauge would be better adapted; and an opinion is widely spread, and authoritatively maintained, that one such locality is the territory included within what may be termed the Punjâb Railway system. The arguments in support of that opinion have been urged with equal force and fairness by Mr. Fowler. That gentleman is not one of those who deem it sufficient to demonstrate the truism, that for all carrying purposes, a broad gauge is, *cæteris paribus*, superior to a narrower gauge. He has distinctly recognised that, "in some districts of India, the population is so sparse, the goods for railway transit so few, and the probability of much increase so remote, that cheap narrow-gauge railways may be introduced with financial and local advantages;" and he has, with equal explicitness, further stated, with special reference to the Indus Valley, that, were it not for certain sections of railway having already been constructed there, he should have "found very little difficulty in deciding in favour of a narrow-gauge line, from its suitability to the very light traffic of that district, and also from its presenting one point of contact only—namely, at Lahore—with the standard gauge." He apprehends, however, in common with all other objectors to this part of the Government plan, that the fact of two sections—both on the standard gauge—already existing, one from Lahore to Mooltan, and the other from Kotree to Kurrachee, would, in the event of the other sections being constructed on a narrower gauge, necessitate extra expenditure so heavy as to more than neutralize the economy immediately attendant on such construction. It is essential, for the vindication of Government, that these apprehensions should be shown to be groundless.

The case stands thus: Continuous railway communication from Peshawur to Kurrachee, a distance altogether of 1,092 miles, being the desideratum, two sections, namely, from Lahore to Mooltan, 214 miles, and from Kotree to Kurrachee, 105 miles, 319 miles together, have been made; while two, namely, from Peshawur to Lahore, 280 miles, and from Mooltan to Kotree, 493 miles, together 773 miles, remain to be made.

Now the total saving obtainable on these two latter sections by the adoption of the mètre gauge, instead of the 5 ft. 6 in. gauge, has been calculated in detail by Mr. Fowler, and also by Mr. Lee Smith, with results which, after certain necessary corrections for inaccuracies in matters of fact, may be exhibited as follows:—

Mr. Fowler's Estimate (not including Indus Crossings).

—	5 Ft. 6 In. Gauge. Cost per Mile.	3 Ft. 6 In. Gauge. Cost per Mile.	Difference per Mile.	Addition for Reduction to Mètre Gauge.	Total Saving per Mile.	Total Mileage.	Total Saving.
	£	£	£	£	£		£
Peshawur to Lahore	9,021	8,227	794	+ 37	= 831	× 280	232,680
Mooltan to Kotree .	6,367	5,501	866	+ 37	= 903	× 493	445,179
							£677,859

Mr. Lee Smith's Estimate (including Indus Crossings).

—	5 Ft. 6 In. Gauge. Total Cost.	3 Ft. 3 In. Gauge. Total Cost.	Deduct on Account of 30 Miles difference in Length between Lines compared.	—	Total Saving.	Grand Total.
	£	£	£	£	£	£
Peshawur to Lahore	3,712,440	3,882,375	− 348,060	= 3,534,315	178,125	
Mooltan to Kotree .	3,895,631	3,161,277	. . .	. . . .	734,354	
						£912,479

Assuming, on the grounds stated in the early part of this Paper, the rate of saving to be £1,000 per mile, the total saving by constructing both the Lahore-Peshawur, and the Mooltan-Kotree sections on the mètre gauge, instead of on the standard gauge, will be £773,000. By the engineers of the Indian Government it is, according to the latest advices, estimated at £750,000.

To recapitulate—the total saving by the adoption of the mètre gauge on the two sections in question is estimated :—

	£
By Mr. Fowler, at about	680,000
By Mr. Lee Smith, at a little more than	900,000
By the Engineers of the Indian Government	750,000
On a balance struck between Mr. Fowler and Mr. Hawkshaw, it may be taken at	770,000

In the calculations about to be made, the figures employed will be those of Mr. Fowler, as being the least favourable to the Government.

The two existing sections of the Punjâb system being on the standard gauge, if the one mètre-gauge section is to be interposed between them, and another placed as an outside link of the whole chain, the combination of the four sections will result rather in a series of most inconvenient dislocations, than in anything deserving to be styled a system, unless each of the standard-gauge sections be either fitted with a third rail, or have one of its rails taken up and relaid on the mètre gauge. Mr. Fowler recommends, as the next best plan to the standard gauge throughout, that a third rail should be laid from Lahore to Mooltan, and that the rails between Kotree and Kurrachee should be relaid at mètre distance, and the cost of the two operations is estimated by him at £327,177, which, being deducted from the saving of £680,000, obtainable by making the two new sections on the mètre gauge, would leave a balance of only £352,823.

The necessity for this deduction is not to be gainsaid; but Mr. Fowler likewise demands another of £320,700, for the provision of rolling stock for working through-traffic on the narrow gauge between Mooltan and Lahore, and also for an extra supply of narrow-gauge rolling stock from Kurrachee to Peshawur for military contingencies; and this demand he makes on the assumption that the narrow gauge employed is to be 3 ft. 6 in. If he had assumed a mètre gauge, his claim would have been proportionately increased.

By deducting, however, only the lesser sum actually stated, he would bring down the original saving of £680,000 to about £30,000; and it must, in candour, be owned, that not only does

Mr. Lee Smith, but likewise General Strachey, Colonel Dickens, and Mr. Meadows Rendel, whose bias may reasonably be supposed to be towards the Government plans, quite concur in recognising the principle on which the greater part of this second deduction of Mr. Fowler's is proposed by him to be made.

Nevertheless, and notwithstanding so imposing an array of adverse authority, it is respectfully submitted that not the smallest deduction on this account ought to be allowed.

Considering, first, the section from Mooltan to Lahore, the existing quantity of broad-gauge rolling stock thereon either is sufficient for all expected traffic, whether through, or local, or it is not. If it is not, then, in case the broad gauge had been adopted for the adjoining sections also, it would have been indispensable to provide additional broad-gauge rolling stock for the Mooltan-Lahore section; the cost of which addition would certainly have been at least equal to that of the quantity of mètre-gauge stock requisite in order to render the total amount of rolling stock, broad and narrow, capable of conveying all the traffic on a mixed gauge. If, on the other hand, the present quantity of broad-gauge rolling stock be sufficient, then, when supplemented by a quantity of mètre-gauge rolling stock for use on a mixed gauge, the total of broad-gauge stock would obviously be in excess of the quantity required, to the exact extent to which it had been supplemented by narrow-gauge stock; and the difference would be available for sale or transfer to the broad-gauge lines, the sale proceeds or appraised value serving as a complete set-off against the money spent on the narrow-gauge stock.

Similarly, for the Lahore-Peshawur section, the cost of providing rolling stock sufficient for ordinary traffic would be the same whether the gauge were broad or narrow, or the difference, if there were any, would be in favour of the mètre gauge; so that, whatever necessity there was for providing additional stock for military contingencies, the necessity would be the same for both gauges, the cost also being the same, or, if anything, less for the narrow gauge. It is thus abundantly clear that, in comparing the cost of the proposed mixed gauge with that of the standard gauge, for the entire Punjâb system, there is no valid reason for augmenting the former with one penny on account of extra rolling stock; and, the addition made on that account by Mr. Fowler being withdrawn, the saving by the adoption of the mixed gauge remains, as virtually admitted by himself, at £352,823.

Here, however, it must be pointed out that all comparisons hitherto made, whether by Mr. Fowler or others, between broad and narrow gauge for the Punjâb, have proceeded on the supposition that the Punjâb railway system will be complete when, by the filling up of the present gap between Kotree and Lahore, and by an extension from Lahore to Peshawur, a continuous trunk line shall have been formed from the last-named town to the port of Kurrachee. This, however, is by no means the case. The purposes which the Punjâb system of railways has in view are rather strategical than commercial, and will be very imperfectly answered, unless one branch at least be led off westward from the trunk line. The branch particularly referred to is one of about 180 miles, starting from Sukkur, on the Indus, and terminating, in the first instance, at Dadur, at the mouth of the Bolan Pass. This is a work almost certain to follow very speedily upon the completion of the trunk line, and all the more speedily by reason of the sense of common interest which is fast growing up between British India and Afghanistan, in view of Russia's portentously rapid progress in Central Asia. It is further to be noted, that the connection of the Indus Valley railways with those of Rajpootana is a project regarded by the Indian Government as one which may deserve to be undertaken at some future period. The aggregate length of these prospective lines could scarcely be less than 400 miles; and, as the determination of their gauge would obviously depend upon the one selected for those of the Indus Valley, the choice of the mètre gauge instead of the standard gauge for these latter would, taking £1,000 per mile as the difference of cost between the two, occasion a saving of £400,000 upon the prospective lines. Of this additional sum, however, only the £180,000 assignable to the Dadur line shall here be taken into account; but that much being added to the £352,823, with which the narrow gauge has already been shown to be on Mr. Fowler's principles entitled to be credited in respect to the Punjâb, will raise the total saving consequent on its adoption in that quarter to £532,823.

This being premised, the inquiry may now be made as to what extent such large pecuniary advantage would be counterbalanced by the disadvantages consequent on break of gauge. Here it is at the outset to be observed that the disadvantages in question, consisting mainly in what may, with respect to passengers as well as goods, be termed break of bulk by change of carriages, would, so far as import traffic is concerned, be only partially obviated by the adoption of a light standard, instead of a light mètre, gauge. The only railway that abuts on the Punjâb from the east being, like all other railways of the guaranteed companies, laid with rails heavier by one-third than those proposed for the Punjâb, even by the advocates of the broad gauge, their proportionably heavier engines could not travel on the Punjâb light lines without ruining them. All through-traffic entering the Punjâb from the eastward would, therefore, have to change engines, if not carriages; and the trains of carriages, if not changed, would have to be broken up and divided into shorter trains, in order to admit of their being hauled by the less powerful engines of the light lines. On the other hand, the export traffic trains, when entering on the heavy lines to the eastward, would either continue to be hauled by light engines unequal to heavy-line speed, or, if taken in tow by heavy-line engines, would be hauled by those engines at the expense of considerable waste of power.

Still, it cannot be denied that some evil would be attendant on the break of gauge. All that is desired is to prevent its being exaggerated. An endeavour will now be made to determine as nearly as possible its real amount.

The evil in the case of the Punjâb is of two kinds—mercantile and strategical; for the inconvenience to which private passengers might be subjected, by having to change carriages once in a long journey, is as little worthy of serious consideration, as that which all suffer through having occasionally to take a cab to a station instead of being able to enter a train from our own doorstep. As regards goods, the gravity of the evil may be measured by the quantity of goods that would have to be transladen. There are two points at which such translading might take place, Lahore and Mooltan; at Lahore, of goods either arriving from the north and proceeding in the direction of Umritsur and Delhi, or arriving from Umritsur, or places beyond, and proceeding towards Peshawur; at Mooltan, either of goods arriving from the south and destined for ulterior conveyance by the broad gauge east of Lahore, or of goods which, having been brought by the same lines to Lahore for conveyance to places south of Mooltan, had not been transferred to the narrow gauge at Lahore, and therefore required to be so transferred at Mooltan. Now, of these last two descriptions of goods the quantity may be safely pronounced to be *nil.* According to the latest trade statistics, the total imports into Mooltan from all places east of Lahore was, in 1870-71, only 10,530 tons, the exports from Mooltan to the same places being under 2,400 tons; and a glance at the map will suffice to show that no appreciable portion of this insignificant traffic can have emanated from, or been destined for, the half-desert tracts extending for a considerable distance to the south of Mooltan.

At Lahore, the other point of meeting of the gauges, the state of things is somewhat, but not materially, different. The quantity of traffic passing through that city in 1870-71, either from the eastward towards Peshawur, or eastwardly from Peshawur and places intermediate, was, according to the same statistical tables, as follows :—

Imports.	414 tons.
Exports.	112 ,,
Total	526 ,,

Supposing that, on the completion of the Lahore and Peshawur railway, these quantities will be doubled—becoming a total of 1,052 tons; and that the out-turn of the Jhelum salt mines will simultaneously rise from 40,000 tons to 100,000 tons, and that not more than one-half of this quantity will either be consumed within the territory of the five rivers or sent westward into Afghanistan, the other half being exported in the direction of Delhi, notwithstanding that only 13,000 tons seem to be as yet so exported annually, and notwithstanding also that it will thereupon come almost immediately into competition with the produce of the Sambhur Lake, even then, and after all this amplification, the aggregate traffic compelled, by break of gauge, to break bulk at Lahore will be no more than 51,052 tons. Now fourpence per ton is pretty generally considered to be the maximum representative in cash of the commercial ill-effects of break of gauge; 51,052 fourpences, therefore, or £850 per annum, or interest at £5 per cent. on a principal of £17,000, represents the utmost commercial harm that can be expected to be done by break of gauge between the railway systems of the Punjâb and of the rest of India. The considerations that recommend an extra outlay of between £500,000 and £600,000 to prevent £17,000 worth of harm must needs be other than commercial.

The strategic considerations are these :—

First. With the Punjâb lines on the mètre gauge, all troops and military stores arriving at Lahore, *en route* either for places south of Mooltan, or for places in the direction of Peshawur, would have to change carriages at Mooltan or Lahore. Secondly. However grave the emergency, only the bare rolling stock of the Punjâb lines themselves will be available for transport upon them; whereas, if those lines were broad-gauge, their rolling stock might be supplemented to any extent by draughts upon the 5,000 miles of broad-gauge lines eastward of the Indus. This is the character of the strategical evils. Their imagined importance may of course be magnified or diminished at pleasure, and there will perhaps be no great difficulty in showing that their importance is somewhat unduly magnified by those who, like a distinguished Member of this Institution, "take for granted" that a prominent motive for establishing continuous railway communication between Peshawur and Kurrachee is the facility which will thereby be afforded "for moving large masses of troops, and for concentrating them in particular districts in the quickest possible time." The only conceivable contingencies in which the presence of large masses of troops will be required in the Punjâb are such as, like, for instance, a Russian invasion, cannot fail to cast their shadows before them so long beforehand, as to allow the Indian Government, without the least hurry and with the most complete deliberation, not only to mass whatever troops, artillery, and military stores might be deemed necessary at Lahore as a basis of operations, but also to distribute troops fully equipped amongst whatever advanced posts it might think proper to occupy. Thenceforward the broad-gauge railways of the main Indian system would never have to bring up troops to be passed on through Lahore without stopping. Their share in the business of the campaign would consist in maintaining, at its proper complement, the reserve of men and material at Lahore. Or if, in some unforeseen emergency, a regiment ever did arrive by rail at Lahore requiring to be sent forward immediately, the only time lost would be the half-hour or so spent by the men in walking from the broad-gauge train to a narrow-gauge train, already laden, in anticipation of their arrival, with whatever guns, ammunition, &c., were needed for their full equipment. This occasional half-hour or so would be the only delay (if any) which ever could be caused by break of gauge.

Respecting the restriction of the projected Punjâb lines to their own proper rolling stock, and their inability to borrow from the main Indian system, it is, in the first place, to be observed that, even though the Punjâb lines were of the standard gauge, it is only carriages and wagons that they could borrow from heavy broad-gauge lines. Heavy-line engines could not be permitted to travel upon their light rails; so that, in order to be able to utilize on emergency the borrowed vehicles, it would be necessary always to maintain on the Punjâb lines a duly-proportioned number of reserve engines to haul them, the enormous expense of which would of itself be an insuperable objection to borrowing.

Secondly. Even though this difficulty did not exist, and even though all the engines and all the vehicles of the 5,000 miles of broad gauge were capable of being used, and available for use, on the Punjâb lines, there would be not the smallest occasion for them there. The rolling stock of the Punjâb lines themselves would be equal to all possible demands. The neighbourhood of Peshawur, near the entrance of the Khyber Pass, and the neighbourhood of Dadur, at the mouth of the Bolan Pass, are the only localities at which an European, or Europeanized, invader would have to be encountered. Let him, then, be supposed to make his appearance simultaneously at both places, and, to put the case as badly as possible, let a host of Beloochees be supposed to be at the same time giving trouble anywhere between Kurrachee and Sukkur. Even then no question of moving by rail complete army corps could arise. Unless the very genius of folly had presided over the previous dispositions, the despatch for a few days together of a regiment a day, every alternate day, from Lahore towards Peshawur, and from Lahore to Dadur, and of a regiment northwards from Kurrachee, as often as one arrived at that port by sea, is the utmost requirement to be seriously contemplated. Now, although the provision of rolling stock for the future Punjâb lines is intended to be much below that of most existing Indian railways—although, while, according to Mr. Hawkshaw, the average complement of the latter is about one engine, with vehicles in proportion, for every five miles, the Government authorities are of opinion that for the lesser traffic of the Punjâb one engine and thirty vehicles for every thirteen miles may possibly suffice—yet, even with rolling stock at this exceedingly low rate, it has been demonstrated by careful and minutely detailed calculations that, in the course of a week, 12,000 combatants of all arms, infantry, cavalry, and artillery, fully equipped, and with a month's rations, could easily be moved from Lahore to Sukkur, or 11,000 from Lahore to Peshawur, or three corps of 4,000 each, one from Lahore to Peshawur, a second from Lahore to Sukkur, and a third from Kurrachee to Sukkur.

The case for the Government of India stands thus: By making the Punjâb lines on the mètre gauge it will save £530,000, at the lowest computation. To have adopted a light standard, instead of a mètre gauge, would have occasioned a waste of a like amount. against which there would not have been the smallest strategical set-off, nor any other compensation of any kind, except a slightly increased commercial convenience, not exceeding in capitalized value £17,000 at the outside.

It remains only to be said that this vindication of the Indian

Government is offered by a volunteer advocate, who does not pretend to have received a brief. Quite possibly therefore he may have inadequately treated some points, or even completely overlooked others, on which that Government, if consulted, might have desired to lay especial stress.

The Paper is illustrated by a map, from which Plate 8 has been compiled.

Ed. Saunders Geog'

India Office London 187.

Mr. W. P. Andrew (Chairman of the Scinde, Punjâb, and Delhi railways) said he had listened to the Paper with much interest and satisfaction; inasmuch as it was the production of a well-known advocate of the proposed narrow gauge; and because it showed how little, even in such skilful and practised hands, could be said in favour of a crotchet which, if imported into the railway system of India, would utterly destroy the usefulness and importance of the lines which he had the honour to represent.

In the first place, he would endeavour to clear the ground by saying that cheap railways, and a break of gauge, were two distinct questions. Twenty years ago he had himself advocated the introduction of cheap railways into India, and he had heard nothing novel in the Paper read on this occasion unless it were the gauge of 3 ft. $3\frac{3}{8}$ in., and that a break of gauge was no serious disadvantage.

The Paper would lead the Institution to imagine that the Author, like Rip Van Winkle, had been asleep for the last twenty-five years, and that he had never heard of the disasters, the confusion, and the loss that had occurred in England from a break of gauge: as he had now proposed, for adoption, ideas which men, who had not been asleep, had long since found impracticable, and had therefore abandoned. All who were interested in railways, in India, must deplore the delay which had occurred from the discussion of this most unfortunate crotchet. All must deplore that the Indus Valley line of railway had been so long delayed, inasmuch as it was beyond question the most important political and strategic line in India—looking to the portentous approach of Russia towards the confines of the Indian empire. Of all the most eminent men connected with India—and he had been in correspondence with a great many—there was not a single one who had not attached the utmost strategic value to the Indus Valley line: Lord Lawrence, Sir Bartle Frere, the late lamented Sir Donald McLeod, Lord Napier of Magdala, and many others, all attached the greatest importance to it; and was it now to be supposed that the Government was going to make this great line almost worthless, for political purposes? The Government proposed to introduce within Indian territory a break of gauge —the very means—be it observed—which Russia had established at her frontier to hamper the movements of any invader. Had a break of gauge existed between France and Germany, the siege of Paris would, in all probability, never have taken place. It was evident that this 'toy line,' which was proposed, could never carry heavy ordnance, and horses, and the munitions of war, with rapidity, certainty, and despatch. Many eminent engineers had told him that it was impossible: at all events, it must be admitted that it could not carry those heavy munitions of war with the same ease and certainty as a line of wider gauge.

The existing gauge was introduced under the authority of Lord Dalhousie, after very considerable investigation, and there did not appear to be any reasonable objection to it. As to saying that a break of gauge was a matter of very little importance, from the Author's description of a regiment marching from one line to another, with all the munitions and all the artillery comfortably arranged in another train on another gauge on the other side of the platform—one would have thought he was organising a pleasant excursion to the 'Star and Garter' at Richmond, instead of handling a body of troops with their camp followers and baggage. He made no reference to the failures and confusion incident to the management of a large body of men and a large amount of heavy material under such circumstances. The real evils were well known to all who were connected with the management of railways. Mr. Andrew trusted there were some present who would give their experience of the evils, confusion, and loss, incident to a break of gauge on the Great Western line. If so, they would state that the evils were so great that, sooner than continue to suffer the loss and confusion, they were induced to relay the line, and to make it a continuous narrow-gauge line instead of a broad-gauge line.

The difficulty and confusion involved in the movement of troops, especially in a country like India, although considered of little account by the Author, were well known to those who had had any experience of campaigns in that country. Even if the fear of complications arising from the portentous advances of Russia should prove to be exaggerated, or groundless, there were ample reasons of a political and strategic character why the railway system of the north-western frontier should be made as perfectly adapted as possible for strategic purposes, instead of being rendered inefficient and comparatively useless, as it would be if a break of gauge was introduced. It was well known with what rapidity the spirit of hostility spread among the fanatic tribes who composed the population both of portions of the British Indian territory and of that immediately beyond the borders. As an instance of this, he might mention the case of the Umbeyla campaign, about ten years since. When this campaign was undertaken, a well equipped force of about 5,000 men was considered sufficient.

But when this force had occupied the Umbeyla Pass, the General commanding found it would not be prudent to advance further without first obtaining a reinforcement of 2,000 men to hold the pass, which was only about 40 miles from Attock and 3 miles beyond the border. And so rapidly did the spirit of hostility spread among the fanatic tribes along the frontier, that, by the time the desired reinforcement arrived, a second reinforcement was found to be required, thus rendering the movement of regiments repeatedly necessary from post to post along the line by which the troops advanced. It was the opinion of the highest authorities on the spot that had 2,000 men been promptly available in the first instance, the putting down of the outbreak would have been the work of a few days, instead of being one of considerable time and difficulty, and attended with heavy loss of life as well as with great expenditure of money.

Mr. Andrew felt, personally, a special interest in this question, inasmuch as he had planned and advocated for many years past the Indus Valley system of railways, with branches to the Khyber and Bolan passes. He feared the Government were by no means alive to the great political importance of that system of railways, which, not only for commercial purposes, but still more for political and strategic reasons, he desired to see completed in the most efficient manner possible. In illustration of the imperial importance of this question, he might be permitted to quote some remarks which he had addressed to Lord Palmerston, in 1857, when Mr. Andrew headed a large and influential deputation to urge upon the support of Government the claims of the proposed Euphrates Valley Railway. On that occasion he stated that "The grand object was to connect England with the north-west frontier of India by steam transit through the Euphrates and Indus Valleys. The latter would render movable to either the Khyber or the Bolan, the two gates of India, the flower of the British army cantoned in the Punjâb; and the Euphrates and Indus lines being connected by means of steamers, we should be enabled to threaten the flank and rear of any force advancing through Persia towards India. So that the invasion of India would by this great scheme be placed beyond even speculation; and it would be evident that the great army of India of 300,000 men, being united by this means to the army of England, the mutual support they would render each other would quadruple the power and ascendancy of this country, and promote powerfully the progress, and the freedom, and the peace of the world."

He could not agree with the Author that it was probable we should have ample notice of any hostile movement on the part of the Russians to enable due preparations to be made for their reception.

There was one circumstance that the Author had alluded to, regarding the tax-payer of India. Now, India was a great country—possessing two hundred millions of people—as large as the whole of Europe exclusive of Russia. The commerce of the country, since railways were introduced, had increased at an enormous rate. Those who, like himself, were connected with Indian railways, had sent out about 6,000,000 tons of materials, conveyed in between 7,000 and 8,000 ships; and they did imagine that the large amount of money they had sent out also had had some beneficial effect on this very pitiable and most interesting tax-payer. They had sent out money for investment in India; and they thought if the Indian tax-payer had to pay £1,600,000 per annum, to make up the guaranteed interest on the railways, the tax-payer had reaped some little advantage in having, in many instances, three times the usual wages; in being well clothed instead of being almost naked, and being well fed instead of half starved; and the farmer, in the enhanced prices of produce and the increased cultivation of the land; and the merchant, in the facilities for the transport and sale of his goods, had benefited to an enormous extent from British capital—not Indian capital. And what was it the tax-payer had to pay? £1,600,000 per annum for all these enormous benefits! It was less than twopence per head. He did not think it fair to bring forward the tax-payer without stating at the same time what he got for his money. If he paid two-pence he got not only a very good sixpence in return, but other benefits which at present he could not estimate.

The commerce of India, as he had already stated, increased to an enormous extent after the introduction of railways. In 1834–35 it amounted to fourteen millions sterling. Then there were no railways. In 1854–55 it amounted to about thirty-five millions, when there were 150 miles of railway constructed. From that time it increased at the rate of eight millions per annum till 1865–66, when it amounted to one hundred and twenty-three millions sterling. That the commerce had not increased since that period was owing to exceptional circumstances, which he had no doubt would soon pass away.

The following memorandum would show the rapid increase which had taken place in the trade and revenue of India during recent years, since the introduction of railways into that country:—

TRADE OF INDIA.

Year.	Imports.	Exports.	Total.	Remarks.
	£	£	£	
1834–35			14,000,000	Average increase from 1834–35 to 1854–55 about £1,000,000 sterling per annum, there being in 1854-55 only about 150 miles of railway open.
1854–55			35,000,000	
1861–62	37,272,417	37,000,397	74,272,814	Average increase from 1854–55 to 1870–71, during which period the railways have been rapidly pushed forward, upwards of £3,500,000 per annum.
1862–63	43,141,351	48,970,785	92,112,136	
1863–64	50,108,171	66,895,884	117,004,055	
1864–65	49,514,275	69,471,794	118,986,069	
1865–66	56,156,529	67,656,477	123,813,006	
1866–67[1]	42,275,619[1]	44,291,497[1]	86,567,116[1]	
1867–68	47,481,157	52,446,002	99,927,159	
1868–69	51,146,095	54,457,744	105,603,839	
1869–70	46,882,326	53,513,728	100,396,054	
1870–71	38,858,728	57,818,022	96,676,750	

[1] Eleven months only.

REVENUE OF INDIA.

Year.	Amount.
	£
1850	27,522,337
1855	29,133,050
1860	39,705,022
1865	45,652,897
1870	50,901,081
1871	51,413,686

DEBT OF INDIA IN 1871.

£111,542,208, or little more than two years' revenue.

Alluding to the Punjâb railway, the Author had mentioned the small traffic which existed on that line, but Mr. Andrew would like to know whose fault it was that the traffic was small? They had in Scinde 106 miles of railway, and in the Punjâb 550 miles, with a gap between of 480 miles. They had, as it were, one part of the line in France and the other part in Spain, with an interval between, and they were not allowed to make the intervening link; and yet they were told it was a line of small traffic. Nothing could be more unreasonable. The Punjâb, which had been described as the "Bulwark of British India," was an immense territory, comprising within its borders an area of nearly

200,000 square miles, with a population of 22,000,000 subject to British rule or influence. So great were its capabilities that it had been estimated by Lord Lawrence, when Chief Commissioner of the Province, to be capable of producing half a million tons of cereals for export annually, without in the least degree interfering with the requirements of the inhabitants themselves.

The charge for transhipment of goods from one gauge to another was estimated by the Author at 4*d.* per ton. Now it would be found from Mr. Hawkshaw's report, that at the time the discussion relative to the gauges was going on, one person estimated it at 4*d.*, another at 8*d.*, and another at 1*s.* per ton; but Mr. Hawkshaw stated that all these estimates were fallacious, inasmuch as the loss arising from confusion and delay exceeded infinitely either of those sums.

In contrast to the views entertained by the Author, who, for the one solitary reason of a so-called economy, would seriously impair the efficiency of this most important portion of the very backbone of the Indian railway system, it should be mentioned that Lord Salisbury, in a speech at Manchester in 1868, in reference to proposed railways in India, had urged that Government ought not solely to regard the question as one of direct profit, as he considered that even in the case of lines which did not yield a direct profit, the Government were more than compensated for any outlay which they incurred. There might also be mentioned a despatch addressed by Sir Stafford Northcote, when Secretary of State, to the Governor-General on the 24th of November, 1868. In this despatch the Secretary of State observed:—"The political and military advantages of present commercial railways to the Government would be cheaply purchased even were the railway system more costly to the Government than it is." It could only be hoped that the question which the Members were assembled to discuss would yet be decided on broader and more worthy grounds than those adduced by the Author.

Mr. T. E. Harrison, V.P., said that he would endeavour strictly to confine himself to the arguments of the Paper. He might say, at the outset, that he had had no connection with Indian railways, but in England he had not only constructed many hundreds of miles of railways, but he had also had to work and manage them; and in the observations which he proposed to address to the meeting he would draw from the experience he had so gained, to illustrate the views to which he proposed to give expression.

The Paper stated that, "practically, the broad gauge is never adopted except when broad, heavy vehicles, nor the narrow gauge, except when comparatively narrow and light vehicles, are intended to be used." Now he took exception to that being laid down as a matter of fact. The original Newcastle and Carlisle railway, which was 60 miles in length, was worked for upwards of twenty years entirely by light engines, light carriages, and light wagons, and he believed that some of that railway stock was still in existence after nearly forty years of wear; and to say that only heavy vehicles were introduced on broad-gauge lines was a mistake, because many of the goods wagons referred to did not weigh more than $2\frac{1}{4}$ tons or $2\frac{1}{2}$ tons, and carried 5 tons of load. Again, it was not true as regarded the narrow-gauge lines, because, in Canada, on the Grey and Bruce and Toronto railway, the cars in use upon that line, though of only 3 ft. 6 in. gauge, were 8 ft. wide and 36 ft. long: therefore when he saw such a statement as that, he could not but call attention to it as not being in accordance with facts.

He would now proceed to the question of figures. It was broadly stated, in the commencement of the Paper, that the case of the Indian Government was based upon one solitary reason—that of economy; and it was admitted that the whole question depended upon whether that economy was real or imaginary. The Author gave two estimates made by men of great eminence—Mr. Hawkshaw and Mr. Fowler. Mr. Harrison found, on putting them side by side, there were great discrepancies between them.

He quite agreed with the general proposition laid down, that a narrow-gauge line could be made more cheaply than a broad-gauge line. He did not think any one would, for a moment, dispute that; but the question arose, what was the extent of that economy? The estimates gave the saving in each item per mile. The first item was land,—Mr. Hawkshaw, £10, and Mr. Fowler, nothing. The next, earthwork,—Mr. Hawkshaw, £100; Mr. Fowler, £37: then bridges,—Mr. Hawkshaw, £50; Mr. Fowler, £83: sleepers and ballast,—Mr. Hawkshaw, £200; Mr. Fowler, £500. Total: Mr. Hawkshaw, £360; Mr. Fowler, £620; Mr. Fowler being £260 in excess of Mr. Hawkshaw. When a document exhibited so great a discrepancy in the estimates of gentlemen of such high position, the natural inquiry was, why did this discrepancy exist? Mr. Harrison had endeavoured, from such information as he had been able to obtain, to arrive at an analysis of that discrepancy.

In the first place, he took the item of land, which Mr. Hawkshaw put at £10, and Mr. Fowler, at nothing; and he concluded that the Author assumed that to be an omission, as he added £10 to

Mr. Fowler's estimate afterwards; but the whole extent was a question of a quarter of an acre of land per mile—strictly, it was 0·27 acre per mile—and the question was, what was the value of an acre of land in India? He saw from a report by Major Bonus, in his estimate of the land for the Indus Valley line, that the maximum value he attached to the land was 27 rupees per acre. Then the value of a quarter of an acre would be 13*s.* 6*d.*

That, Mr. Harrison fancied, was one of those items which might, without difficulty, be reduced to something like a certainty. As regarded the earthwork, if the additional width of 2 ft. 3 in., the difference between the mètre gauge and the 5 ft. 6 in. gauge, was taken as the basis of the calculation, the total amount was equal to 440 cubic yards of earthwork per mile of road a foot in height; and he was told that the average cost of earthwork was 5 rupees per 1,000 ft., or equal to £7 7*s.* for every foot-height per mile; and, taking an average height of 5 ft. for a cheap line, the cost would be £36 15*s.*, or, practically, what Mr. Fowler had put it at. Still, there were elements by which such a calculation could be accurately made.

On the subject of the bridges he had no means of judging whether Mr. Hawkshaw's £50, or Mr. Fowler's £83, per mile was right. All he would say was, in making the design for girder bridges which might be used on a light line of railway, of the standard gauge, he should be disposed to err on the right side, by making them stronger than calculating the minimum loads they had to carry: therefore, on that ground, he should take the higher of the two values.

When he came to the question of sleepers and ballast, there was a discrepancy of 150 per cent. between Mr. Hawkshaw and Mr. Fowler. Now he had analysed the basis on which Mr. Fowler made his estimate, and it was quite clear on the face of it, on making the comparison between the narrow gauge and the broad guage, how that difference arose. On the question of sleepers, which formed the most important item, Mr. Fowler took the section of the sleeper for the mètre gauge, at 8 in. by 4 in.; whereas, when he took the section for the broad gauge, he made that section 9 in. by 4½in.

Now it was proposed that the weight of the rails should be the same in both cases, which meant that the loads that were to traverse them were the same also; and Mr. Harrison had yet to learn why, as the load was the same, and the rails were the same, the sectional area of the sleepers was to be different. He had laid thousands of sleepers of the section of 8 in. by 4 in. on a 4 ft. 8½ in. gauge, forty years ago on one of the earliest lines. All the sleepers on that line were of that sectional area, the weight of rails was 40 lbs. per yard, and over a portion of that line the traffic between England and Scotland ran for about four years. Therefore, if the sectional area of 8 in. by 4 in. was sufficient for a gauge of 3 ft. 6 in., he had no hesitation in saying it was sufficient for a gauge of 5 ft. 6 in. with the same weight of rail and of passing load. But the difference in sectional area of the sleepers adopted by Mr. Fowler, caused a difference in his estimate of £150 per mile.

Then, again, on the question of ballast, Mr. Fowler took the depth of the ballast for the mètre gauge at 1 ft., but for the 5 ft. 6 in. gauge he took a depth of 1 ft. 3 in. If 1 ft. depth of ballast was sufficient for the mètre gauge, it was sufficient for the 5 ft. 6 in. gauge; therefore, that was a point on which he joined issue with Mr. Fowler, as to whether in that item a fair comparison had been made between the two gauges, and, if not, it made a difference of £81 per mile.

Then Mr. Fowler took an addition of £10 per mile for laying the additional gauge. What it might exactly be Mr. Harrison could not say, but he should put it at not more than £2 per mile or £3 per mile at the outside, because, in the manipulation of the laying of the rails, the only additional cost was connected with the handling of the larger sized sleeper. Mr. Fowler took the difference in sidings at 10 per cent., and said, if the main line cost a given sum per mile more than the mètre gauge, and all the sidings were the same, they must add so much to the cost per mile. In that, Mr. Harrison entirely agreed; but putting the whole together the result was only £378 per mile, instead of £633 per mile, as stated by Mr. Fowler. Mr. Harrison could not help feeling, that when the Author added together the two sums, of Mr. Hawkshaw's estimate, and of Mr. Fowler's estimate, with the addition of £10 for land, and then took an average of the whole, such a mode of making an estimate hardly commended itself as a proper mode of determining a question of such vital importance to our vast Indian empire. To take the average of two opinions, without a strict investigation of the mode by which those opinions were arrived at, reminded him of the mode he had often seen followed by common juries who assessed the value of land—they took the sum of the amounts given by the witnesses, and took an average of the whole. Now, taking the average, which was £497, as arrived at by the Author, there was added to that, for engineering and agencies, 17½ per cent., or £87 per mile. Mr. Harrison believed that, on many Indian railways, the cost upon the outlay for works for engineering and agencies was that amount; but when the nature of this excess was examined, there were many items which formed that excess which could not for a moment come under the category of works which required an average of the whole of that expenditure. He took the engineering, the setting out of the line, the preparation of plans, the estimate of all the works, which were important items, and it was quite clear these would be expenses per mile equally chargeable upon the narrow gauge and upon the broad gauge, and, therefore, when he saw 17½ per cent. charged as an average of the whole cost, it was clear there ought to be a large deduction made from that item.

Then there was a question of saving of maintenance, which was put at £10 per mile, and capitalised at twenty years' purchase as £200. That, in itself, he did not at all find fault with, but he doubted very much whether the effect of the mode in which it was put was not calculated rather to mislead. It was not expenditure. It was quite clear, that to maintain the sleepers and other works upon the broader gauge, there would be a larger expense in renewals. He did not quarrel with the amount of £10 per mile, but he did not think, when they estimated what the outlay would be, this should be regarded as additional cost.

Then Mr. Hawkshaw had put in his estimate an item of possible saving of £200 per mile for curves. Now Mr. Hawkshaw admitted, not only with regard to that item, but with regard to other items of his estimate, that he had placed them at an amount which he believed would place it beyond the power of cavil; but Mr. Harrison was afraid he should cavil very greatly at this estimate of £200 per mile for curves. He did not know exactly what the nature of the country was, but he was told, that as a rule, sharp curves were not required, yet this was a charge which was proposed to be made applicable, not to special cases, but to the whole of the proposed 10,000 miles of railway throughout India. Now, surely, apart from the question whether £200 per mile was the exact sum, it could not be right—where they had the great majority of the lines, as he was told, through a country in which few or no curves were required—to apply the result of the special cases, and those quite exceptional, to the whole length of lines they were proposing to construct. He further took exception to the question of the saving alleged to be obtainable by the use of sharper curves on the mètre gauge; because, as he understood, there was a limit of 5 chains radius on the mètre gauge, and there was no difficulty whatever in adopting, for such lines, curves of 8 chains radius with the broad gauge. He had such curves at work without the slightest difficulty over many miles of railway and very steep gradients. He had occasion some time ago to examine into this question as to the saving which could be effected by adopting sharp curves. To accurately arrive at the amount, it was necessary to go one step further by taking the additional length of line which the use of sharp curves entailed, and the cost of maintaining and working that additional line, and also to capitalise that additional cost. It would further be necessary to take into account that in many cases the apparent saving, which was solely a question of excavation, was far more than swallowed up if the correct plan was adopted of taking into account the increased cost of making, working, and maintaining the additional length of line: therefore he doubted whether in any case there could be an excess of expenditure of £200 per mile; and under no possible circumstances could such an expenditure be applied to the whole 10,000 miles to be constructed in India.

These items altogether brought up the cost, as given in the Paper, to £1,000 per mile. Now he begged to say distinctly from his own practical experience, if he were going to construct, in England, a mètre-gauge line, as compared with a light broad-gauge line, it would not save £400 a mile; therefore he entirely doubted the accuracy of the basis as set forth in the Paper, and on which, as he understood, the Indian Government had decided to introduce the mètre gauge. Whether the reduction from £1,000 per mile to £400 per mile would alter their ideas or not he could not say, but the whole basis of the Governmental decision, as put forth from the beginning to the end of the Paper, was stated to be that the one solitary reason for adopting a narrow gauge was a belief in its superior economy. It did not state the extent of that economy, but simply that it was a superior economy.

With regard to cheap lines, there were other circumstances beyond the mere question of permanent way which entered into the construction of cheap lines. He had, within the last three years, to make a line in Yorkshire—the Selby and York railway. That line was constructed on the first-class gradient of 1 in 240; but the contractor, happening to find a good brick-field in the centre of the line, laid down, for his own purposes, a permanent way of nearly the whole length of the line. The cuttings were from 18 ft. to 20 ft., and the embankments about the same height. During the whole progress of the line for two years this contractor's permanent way was laid upon the surface, and Mr. Harrison had traveled over it at a speed of 20 miles per hour. He was satisfied that if more attention was devoted to the use, in certain cases, of short and sharp gradients, and in that way getting over the surface, a greater economy would result than was involved in the question of lightness of railway.

So far, then, as to the general question of economy: but now he would take up that which was put forward in the Paper as being by far the most important part of the question, namely, the applicability of the mètre gauge to the Punjâb system of railways—not only of the introduction of the mètre gauge, but of the mixed gauge, and of break of gauge. The Paper stated the proposal was to lay down a third rail in the 214 miles of line, from Lahore to Mooltan. That was a proposal to introduce into a portion of the Indian railways—which was admitted, in the Paper itself, to be one of the most important for strategic purposes—that break of gauge and of mixed gauge, which, in England, he was happy to say, were on the point of being abolished. He had been to a great extent connected incidentally with these questions of break of gauge, and of mixed gauge, and he had always heard from those interested—in South Wales particularly—the break of gauge described as the "curse of the district;" and when lately in South Wales he had heard equal rejoicings that a change had taken place. One gentleman connected with copper-works in Wales told him that the change of system by which the copper ore was taken directly to the works, had resulted in an economy of £1,000 per annum, and that additional income was derived entirely from avoiding loss in copper ore from transhipment.

The saving as between the mètre gauge and the standard gauge, as estimated by Mr. Fowler, was £680,000; but if the views which Mr. Harrison had expressed were at all correct, and he presumed Mr. Fowler had based his estimate on the same basis as his report, that amount would be reduced to a very large extent. It was admitted that there were sets-off to the extent of £327,177 for altering the existing gauge in one case, and for laying down the third rail upon 214 miles of the Lahore railway. Then there was a further item of £320,700 for rolling-stock for through-traffic, the extra narrow-gauge stock, and for military contingencies. Now that item was vouched for, according to the Paper, as necessary by General Strachey, Colonel Dickson, Mr. Fowler, Mr. Lee Smith, and Mr. Rendel; but it was argued by the Author "that not the smallest deduction on this account ought to be allowed." Now, in this case, he would bring to bear that which had been his own experience in these matters, and here he would quote the words of the Paper:

"Considering, first, the section from Mooltan to Lahore, the existing quantity of broad-gauge rolling-stock thereon either is sufficient for all expected traffic, whether through, or local, or it is not. If it is not, then, in case the broad gauge had been adopted for the adjoining sections also, it would have been indispensable to provide additional broad-gauge rolling stock for the Mooltan-Lahore section; the cost of which addition would certainly have been at least equal to that of the quantity of mètre-gauge stock requisite in order to render the total amount of rolling stock, broad and narrow, capable of conveying all the traffic on a mixed gauge."[1]

Then the converse of that proposition was also gone into, and the same argument was also used as to the Lahore and Peshawur railway. Now, wherever two systems of gauge were adopted, the merest tyro in railway management would be aware that it was impossible to do the work with the same amount of stock which was required for an uniform gauge. He did not state this as a matter of opinion, but as a matter of fact, which he was satisfied every railway manager knew to be beyond dispute; but the Author asserted—on what authority was not stated—that not the smallest deduction should be made on that ground. There were many practical instances of it. He would take as an illustration the case of two collieries, each of which thought it was desirable to have their own particular stock; but if the railway company did the work, the stock with which they could do it would be less than the aggregate stock of those collieries. If, on the other hand, the railway company determined to carry a particular portion of their traffic by a particular class of wagons, and the other portion by another class of wagons, it was clear that, to carry that traffic, they must have a larger amount of stock. Then, again, there was the question of the expense of working. When they had the two systems to work, it was utterly impossible they could work those systems by running only the same amount of mileage. They had the mixed gauge; they had two sets of trains, one for the broad gauge, and the other for the narrow gauge; and, in working, they must have a largely increased mileage; thus the fair basis of calculation would be to take that additional mileage as an annual cost, and to capitalise it as a set-off. But that was not done.

Then, again, he did not see anything put down for the increased cost of maintaining the 214 miles of mixed gauge. No one could dispute the fact that there was a large additional cost in maintaining a mixed gauge. He knew that, when the mixed gauge

[1] *Vide* ante, p. 222.

was taken up, on the line at Oxford, the Great Western Company calculated they saved nearly £100 per mile in maintenance of way; and he knew the saving could not be less than a fourth of the cost of maintaining a single gauge; and if that was put at £80 per mile, the increase of £20 per mile—which was the minimum—and capitalized that amount per mile over 200 miles, it would be found there was an amount of £80,000, as a set-off against this £320,700. Then he saw also, at the other end of the line, the whole of the stock of the Scinde railway would be thrown upon the hands of that company, and it must be sold. That line was now of the standard gauge, and that being done away with, they would have that stock to sell, and to supply its place with other stock. He saw no account of the loss which would be sustained by that; and it was well known if a company had stock to sell they would think themselves happy if they realized anything like 50 per cent. of the first cost. If he took all the items together, the conclusion he arrived at was that, so far from this crucial test, the one solitary reason, superior economy, being actually realized, he, on the contrary, had no hesitation in stating that the adoption of this mètre gauge on the Punjâb system of railways would be found to occasion actual and positive increased cost to the Indian Government.

Now there was one other point which he thought had not yet been sufficiently tested anywhere—certainly not in England—and that was, what would be the actual cost of working this mètre gauge. The only instance in England was the Festiniog railway, which he knew and had traveled over, and there the expense of working and maintenance came out at £1,000 per mile. Now, he knew perfectly well that for years the Newcastle and Carlisle line, with a traffic greater than that of the Festiniog railway, never exceeded £500 per mile. What was it in this gauge that caused the Festiniog line to be worked at a cost of £1,000 per mile? He thought that, before assuming as a fact that there was to be this great saving in cost, when the Government were going to adopt an innovation affecting the whole of India, it would be a prudent plan to ascertain with more certainty that which was not referred to in the Paper, namely, whether in the actual working there was any saving at all, and whether there might not be a loss? He held that was a point which was already settled, taking the results at Festiniog as a guide. He was reminded that the Festiniog line was only of 2 ft. gauge. That was true; but the argument had been used, that if a line of 3 ft. 3⅜ in. gauge could be worked more cheaply than a line of 5 ft. 6 in. gauge, then by reducing the gauge to 2 ft. it would be worked more cheaply still; but he believed the reverse would be found to be the case in working.

There were several other points to which he should have been glad to refer; because he found they were matters in which, in a practical point of view, he considered that the assumptions in the Paper were entirely erroneous. But he felt he had trespassed sufficiently long upon the time of the meeting, and many other speakers would be able to go into those matters and to elucidate them.

Mr. J. Hawkshaw, Past-President, said the Paper referred to a former report of his, and, in fact, professed to draw from that report, to a certain extent, the data which led the Author to the conclusions he had stated. But on looking at the Paper and comparing it with his report, from which it purported to make extracts, he had been a good deal puzzled to make out the figures which had been ultimately put forward by the Author.

It purported to deal with averages of figures given by himself, and with certain figures given by Mr. Fowler, in a report made three or four months later; but he could not discover how the conclusions arrived at could be derived from those figures. In his report, Mr. Hawkshaw had nowhere put the saving of the 3 ft. 6 in. gauge at a greater sum than £760 per mile; and Mr. Fowler put that saving in one case—that of the Kotree and Mooltan line—at £866, and in that of the Indus and Peshawur line, at £794; and the average of these two was £830 per mile. If they took these figures, £830 per mile and £760 per mile, they got an average saving, so far, of £795 per mile; and that was the only result he could find from averaging Mr. Fowler's figures and his own. But in that £760 per mile was included a sum of £200 for saving of locomotives. Now although Mr. Hawkshaw had included that sum in an aggregate, yet he stated, for reasons which he gave, that he thought it had no business to be there; and if that £200 was omitted—and the Author seemed to think that it should be omitted—then the average saving derived from his report and Mr. Fowler's report came only to £695 per mile. So far, therefore, if the Author had followed those figures, he would have got only a sum of £695 per mile, instead of £1,000 per mile.

With regard to his own report, it was made entirely for the Eastern Bengal Railway Company, and solely had reference to whether they could judiciously make an extension of that railway on the narrow gauge, instead of on the existing gauge. In making that report he put forward the fullest possible saving that could be arrived at by adopting a narrow gauge; and he now thought he put the items of saving too high. He agreed with Mr. Harrison, that the assumed saving of £200 on curves would never be realised. He could also quite agree with Mr. Harrison, that they never would in India, by adopting the mètre gauge, effect a saving of more than £400 per mile or £500 per mile—possibly not more than £400 per mile. So much for the saving. But there were serious items on the other side of the account. In this country it was well known what those items meant; for that was a very old question, discussed thirty years ago, and which some persons reasoned upon then, as the Author did now; and what were the results? The results had been that those who said the evils of this break of gauge would be too serious to be borne proved to be right; and that those who said they were little and trifling, as some gentlemen then said, had been proved by experience to be quite wrong. The Author said it was admitted—on what authority was not stated—that the money value, in a commercial sense, of a break of gauge was 4*d.* per ton. He need only say, to gentlemen who were acquainted with this subject, that the Author ought not to have stated that any such thing was admitted. In fact, nothing could be more erroneous. Possibly the Author might have got that figure from Mr. Hawkshaw's report; for, in referring to the evils of this change of gauge, and alluding to what occurred thirty years ago, he stated that the commercial inconvenience had been estimated at from 4*d.* to 8*d.* and 1*s.* per ton; but then he went on to say, that experience had shown those estimates to be quite fallacious.

Then the Author measured this question in another way. He dealt with the present income of Indian railways, and said they now only made 3 per cent.; and he seemed to infer, because they only made 3 per cent., they were only carrying three-fifths of the traffic they were intended to carry; and therefore the mètre gauge could carry that amount, &c. Now, an argument of that sort, applied to Indian railways, would mislead. He remembered the time when the Lancashire and Yorkshire railway earned only 2½ per cent.; that company was now about to declare a dividend of 9½ per cent. By parity of reasoning, men living at that day might have said, "This gauge is altogether wrong: you gentlemen do not know what you are about. You are making only 2½ per cent., and you ought to have had a gauge of 2 ft. 9 in." But there was an item which the Author overlooked with regard to the Indian empire, and with regard to the question of dividend. He believed it could be clearly proved that every nation gained as much from every railway that was made as the proprietors gained—nay, he believed it gained much more. He had occasion about the year 1850, at the time the Lancashire and Yorkshire railway was earning only 2½ per cent., to go before a Committee of the House of Commons to advocate a Bill which proposed to increase the tolls, which they thought were too low. The Board of Trade reported against the increase, which was natural; but he thought he satisfied the Committee that, though the Railway Company was only earning 2½ per cent., the districts through which the railway ran were receiving more than that percentage on the capital which had been expended in making the railway. Therefore he must maintain that it was a grievous error in advising those gentlemen who had the control of affairs in India in coming to conclusions as to the extension of railways, to negative the advantages to the country through which they passed. He believed that the gain to India, from the railways, would probably be nearly double the dividend which they afforded to the railway proprietors.

There was another point on which he laid great stress, but of which the Author appeared to think lightly, namely, the questions of the gauge and of the character of the railway, in a strategic point of view. He should not have ventured to have spoken on that branch of the subject had he not, with others, had occasion, at the request of the War Office, to advise as to the means of moving troops in Great Britain by means of the existing railways. They then learnt the difficulty of the task. He thought it of vast importance to a country like India—even more important than to Great Britain — that they should be able to pass troops by railway with the least possible obstruction; but the Author said there would always be ample notice of an invasion of India, and that there would be opportunity for proceeding "with the most complete deliberation" in massing troops at some particular place there to await the invaders. Suppose that the invaders did give notice they were coming, and that the British Government had time to get troops to a certain point with deliberation —if the troops were to be kept waiting at that spot, he should like to know what the expense of that would be? But besides an invasion, might there not also be another Indian mutiny, to put down which the troops might have, at an hour's notice, to be carried with the utmost rapidity to another point? Therefore one effect of this broken network of railways in India must be to delay transport, and to add to the confusion, always too great, in such cases, under the most favourable circumstances; this, in his opinion, apart from all commercial questions, might render the proposal now made, if persisted in, one of the greatest calamities that could be brought upon the country. At all events, he would say, do not proceed with this great "programme," as the Author called it, of making 10,000 miles of mètre gauge, without a thorough and efficient inquiry. Let those gentlemen who supported this measure go before some committee or commission, capable of understanding and of testing their statements. To arrive at a decision without some such previous step, would be, in his opinion, one of the most unusual proceedings that he could imagine in any country. He would not then make any further observations, because some of the remarks he had made had already appeared in his report. He would only add that, neither personally nor professionally, had he any interest in the question of what gauge was adopted in India. He, however, conceived that a most unwise and crude scheme had been suddenly propounded, without due consideration, and that if the Government persisted in carrying it into execution, it would be a consummate act of folly.

Mr. G. P. Bidder, Past-President, said that, being the Consulting Engineer of that particular section of railways in India which had been the first assaulted by this scheme, he had taken, as might be imagined, particular interest in it; in point of fact, he believed he was the first Engineer whose attention was drawn to the project of the introduction of the 3 ft. 6 in. gauge into India. He was called upon by the Directors of the Scinde, Punjâb, and Delhi railways to report his opinion of the probable consequences of such an introduction, and on the 14th of June, 1870, he made his report, in which he did not enter into such details as Mr. Hawkshaw and Mr. Fowler had done, but he stated in general terms that he knew there could not be any saving by the introduction of the exceptional gauge on the Indus Valley railway. He thought it was now necessary that a short statement should be made of the mode in which this question had been introduced in this country by the Indian authorities. Soon after his report had been made to the Scinde Railway Company, another report was obtained from Mr. Hawkshaw ; and then a Commission was appointed—and he would use a strong word—a packed Commission, with a Duke for a dry nurse, to proceed to Norway in one of Her Majesty's yachts to inspect a railway in that country. The Commission went to see a railway, of a narrow gauge, and a more common-place railway it was impossible to find. He knew it very well, and he was an unfortunate shareholder in it; and he only wished that it could be made to pay a dividend; but he did not attribute its non-paying character to the gauge. The railway in question had never yielded any dividend, and he doubted whether it really paid the working expenses; whereas a railway of the ordinary 4 ft. 8½ in. gauge, with which he was also connected, in the same country, paid a dividend of from 5 per cent. to 6 per cent. per annum. If this Commission, to which he had alluded, instead of going to Norway had gone to the West India Docks, and had seen some contractor's engines at their ordinary work there, or had gone to a colliery which could have been pointed out to them, where they would have been shown a 4 ft. gauge altered to the standard gauge of 4 ft. 8½ in:, to obviate the inconvenience and expense resulting from a break of gauge, they would have derived more practical experience than they did from their pleasant trip to Norway.[1] Before quitting the question of exceptionally narrow-gauge railways, he would allude to the Festiniog railway, which was stated to be paying a large dividend, which was mainly assigned to the fact of its being constructed on the narrow-gauge system; whereas, the most superficial inspection of the line would show that the dividend arose entirely from the exceptional character of the traffic—slates packed in conveniently small carriages, traveling down a good working incline to the shipping port, and paying a most unusual rate of freight. These were circumstances rarely to be found combined in other localities.

Agreeing, as he did, with the general conclusions stated by Mr. Harrison and by Mr. Hawkshaw, he would not go over that ground again, but would address himself to the particular case in which he was more especially interested — the alleged economy in the introduction of this gauge for the Indus Valley railway. He was necessarily better acquainted with the condition of that part

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[1] It is deserving of notice, that on the 7th of October, 1872, there was opened, in Norway, a line of 32¼ English miles in length, of a gauge of 3 ft. 6 in., between Christiania and the Port of Drammen. There were upon it some sharp gradients and curves, which required adequate engine power. The general result had been that the engines and the rolling stock had been found to be utterly insufficient. The weight drawn by each engine, its own weight not included, was only 652 cwt., as compared with 1,595 cwt. drawn by the engines on the 4 ft. 8½ in. gauge lines. The traffic had therefore of necessity been confined almost entirely to passengers. The speed attained was, for fast trains with 2 stoppages, 1 hour 40 minutes, or about 19 miles per hour; for ordinary trains with 8 stoppages, 2 hours 13 minutes, or about 14 miles per hour. Up to the present time very little merchandise could be transported. The general result was, that in deference to the public opinion, it had been enacted in the 'Storthing,' or Parliament, that for the future, the State Railways should only be constructed on the standard gauge of 4 ft. 8½ in.; and on that gauge the new State line, 126 English miles in length, *viâ* Frederikshald, to the Swedish frontier, now about to be commenced, would be constructed.—G. P. B.

of the Empire, and his mind had been specially directed to various circumstances connected with it.

Now, assuming Mr. Hawkshaw's figures — £400 per mile, and adding £200 more for maintenance, which, as it was a reversionary value, did not begin for many years; but assuming the saving to be £600 per mile. The number of miles over which it extended was—490 miles for the Indus Valley; and 270 miles for the Peshawur line; making 760 miles in the whole; and £600 per mile over that would represent £456,000. That was the whole advantage they claimed, and that was in construction. Now for the 'per contra' statement.

With regard to the Scinde railway, it was proposed to narrow the existing line. Mr. Fowler assumed the cost to be £500 per mile, equal to £53,000. Then, as Mr. Harrison stated the case, the whole of the rolling stock there must be sold, and must be transported up the Indus Valley to where the ordinary 5 ft. 6 in. gauge prevailed; but this transport must be 500 miles up the river, between Mooltan and Kotree. Now, as an example of what the cost of transport in India was, he might mention that the charge actually made by the East Indian railway, from Calcutta to Delhi, a distance of 1,000 miles, for hauling up engines and wagons, not in steam, but with the ordinary goods' trains, was £350 per engine and £50 per wagon; these charges upon 100 engines and 1,250 wagons, with other incidental expenses, made a total of more than £100,000 paid for railway conveyance.

Then, as to rolling stock, Mr. Harrison had stated the A B C experience of railway traffic. Assume a line broken up into sections, and that there was required a separate stock for each section, there must be a much larger stock than was necessary for working the section throughout, and that position applied more particularly in the Indus Valley, for he had considered the question of traffic, and had advised the Directors as to the cost of the railway and the amount of rolling stock that would be required.

The traffic of the Indus Valley at the present time was represented by steamers, making fortnightly journeys each way. Now speaking, as he was, in the presence of engineers who knew that the principal strain on the rails was due to high speed, he felt assured that they would agree with him, that a speed of 25 miles per hour on light rails of 40 lbs. to the yard, would admit of an ordinary locomotive engine traveling upon them, and as that would be quite adequate to the requirements of the Indus Valley traffic, the existing stock of locomotive engines need not be increased. He also came to the conclusion that, as at present, the wagons were detained at Mooltan and Kotree to be loaded and unloaded, and as this must hereafter be, more or less, the case with a break of gauge, all of this would be avoided by a continuous route, and no additional stock would be required; thus the whole of Mr. Fowler's estimate, amounting to £400,000 for rolling stock on the Indus Valley, would be saved on this section of the line.

The next important saving would be effected in the rolling stock for the extension to Peshawur, as, in case of emergency, recourse might be had to that of the general system, and certainly more than one-half of the stock would be found sufficient; thus a further saving of £106,000 would be realised.

To this must be added the cost of a third rail from Mooltan to Lahore, estimated by Mr. Fowler at £275,000, and the amount of extra cost of maintenance, estimated by Mr. Harrison at £20 per mile capitalised.

Lastly, the extra cost of altering the Lahore station into an interchanging, in place of a through station. It was difficult to estimate this, but, assuredly, it could not cost less than £50,000.

By adding up all these items, namely:—

		£
1.	Altering the gauge on the Scinde railway . . .	53,000
2.	Rolling stock on the Indus Valley	400,000
3.	Ditto on Peshawur extension, one half . . .	106,000
4.	Laying third rail from Mooltan to Lahore . . .	275,000
5.	Extra maintenance of ditto at £20 per mile capitalised	80,000
6.	Altering Lahore station	50,000
	A total was arrived at of	£964,000

Therefore he came to the conclusion that, instead of there being any economy, there would be an absolute additional expense in adopting the narrow gauge, and, therefore, the sole element for its justification was an entire failure in that respect.

Now as to the inconveniences of this proposed system—there was an expression made use of in the Paper which was remarkably applicable to the case. The Author, in referring to the invasion of India by the Russians, had used the expression, the "genius of folly." Mr. Bidder must be permitted to use this felicitous phrase, and to apply it to the introduction of this gauge without having previously ascertained the results; and when a gentleman of the Author's official position talked of 4*d.* per ton as representing the commercial value of the break of gauge, he could not avoid saying that it was the "genius of folly." The Author, a man of great intelligence, living in London, must know that the break of gauge in this country had long been felt to be unendurable, and that the change to an uniform gauge had been made at great expense. Had Sir Daniel Gooch or Mr. Grierson been asked why they made the change, they would have clearly shown the numerous and important evils inherent in the system, apart from the mere cost of transporting the goods from the narrow gauge to the wide gauge, and *vice versâ*, and, therefore, not to have inquired from them the reasons for incurring such cost and inconvenience on such a railway as the Great Western, before a statesman ventured to recommend so vital and detrimental a change in India, deserved to be stigmatized as the "genius of folly." Then the Author ventured on the assertion that it was necessary that the same engine should be used throughout any system of railway, whatever might be the variations in the strength of the rails. He could not possibly have traveled out of London by any of the main lines without seeing the engines changed at different parts of the journey, and at Crewe he would have seen three separate trains propelled by as many engines united into one train drawn by one engine. Even in the rural district of Devonshire he would find a branch railway where the broad-gauge wagons were propelled by a small 'contractor's engine.'

Mr. Bidder must take exception also to the spirit in which the Paper had been drawn up. He alluded to that part in which it was stated that the natives of India were taxed £1,600,000; that being the difference between the net receipts of the railways and the interest paid by the Government. That remark might apply to a great many things, no doubt, but to apply it to the railways of India was the "genius of folly." Was it no advantage to the people of India to be carried at greater speed and at less cost? Was that a tax upon them? Was the postal service no compensation? Was the greater efficiency of the army, and the means of moving that army more rapidly, no compensation? And yet the Author had characterised the difference between the net earnings of the railways and the interest paid on them as a total loss, and an unmitigated tax upon the natives of India. As if the money had been spent on a mere toy.

Now Mr. Bidder could tell them where the waste was, but this was not the proper place nor the proper occasion to do so at any great length. He would, however, give a few instances. The original financial arrangement for executing the Indian State railways, if not altered, was a rare specimen of the very "genius of folly." It was proposed to carry on all the new lines "pari passu," the works to be extended over a period of twenty years. Thus, assuming twenty millions sterling to represent the sum to be expended, the outlay was to be at the rate of one million per annum. The first result would be, that for nearly the whole of that period, the capital would not only be unproductive, but the unfinished works would be a constant source of expense for maintenance, to say nothing of the waste from the decay of the wood and the iron. Besides which, the cost of supervision would be immensely aggravated, and all responsibility be lost by the lapse of time. There were two obvious alternatives, each much more rational. First, by commencing and completing the most important sections as soon as possible, by the concentration of all the resources of the engineering staff upon these works in the application of the outlay of one million per annum. Thus no more ultimate capital would be expended, and the lines, as they were finished, would be a source of convenience and possible profit, instead of being a cause of current outlay. Another plan, and that adapted to the meanest capacity, would be to invest ten millions sterling in the Indian Railway stocks at five per cent., reinvesting the annual income. Thus, in fourteen years, the ten millions would grow to twenty millions, and if judiciously applied would finish the lines by the end of twenty years as originally projected, whilst ten millions of money would be saved, being equal to the anticipated but illusive saving to be effected by introducing the narrow gauge in India.

It had been part of his duty to frame a contract for the construction of the Delhi railway. That was to some extent an experimental work. The line had to cross several very large Indian rivers, with regard to the special features of which no reliable and definite information could be obtained; they had to some extent to grope their way in the dark; and, in order to mitigate the risk to the Company, it was his desire to secure the skill and attention of the Contractors in aid of the work by making them liable for the maintenance of all the work, including the bridges, for a period of three years. The contract was sent out to India to be approved by the authorities there, and it came back with the remark, "The charge for maintenance, both as regards time and amount, is too great. Three years is unusual, and in such a climate two years even is excessive." No doubt, in the opinion and experience of the 'Reporter,' this was true; because the gentleman had never had any experience. He was like the Irish fiddler, who did not know whether he could play or not, because he had never tried. But in the case of the bridges which were injured by a flood, the shortening of the period of maintenance, from three years to one year, involved a loss of £200,000, which would have been entirely obviated by the payment, under the arrangement objected to, of a sum of £90,000, from which there would have been deducted the actual cost the Company had incurred for two years' maintenance of the rest of the line of, say 300 miles in length, which would have reduced it by a very substantial amount.

In another case, a gentleman in high position at Bombay, was directed to advise upon what economy could be effected in the working of the Indus flotilla. That was a mixed question of economy and commercial return; but what he had to look to had nothing to do with the convenience of the public or the commerce —the only thing to be considered was positive saving, and on that point, the report which was made, dated 1st April, 1870, stated:—

" There are no objections to Captain Wood continuing to dispatch boats from Kotree as soon as he has obtained a full cargo; but he should report whether it would not be expedient to make the filling of vessels with cargo the sole condition of departure instead of endeavouring to maintain a fortnightly service. The sooner it appears to Government, that the flotilla is reduced to a strictly commercial service, the better is the prospect of a remunerative return."

These were samples of the way in which these things were investigated in India, but he did not know that they could very well be avoided, because on the inauguration of the railway system the Indian Government enforced upon a very intelligent and able body of men conditions of service which it was impossible effectually to comply with. For instance, they took a military gentleman, who came probably from the building of a barrack, or a church, or some other useful employment, to try his hand at railways. The position was entirely new to him. He had to grope his way, and in time he obtained some practical knowledge; but on promotion he would be removed, and another officer came in his place; so that no responsibility could be fixed upon those gentlemen; and unless a man had an ample knowledge of every branch of engineering the result must necessarily be disappointing. Owing to these circumstances, a vast increase of expense had been thrown upon the Indian railways and the public works in general, which might have been avoided had a more efficient system been adopted.

On the question of this mètre gauge, a 3 ft. 6 in. gauge was first talked of, and was then suddenly altered into the mètre gauge, for what reason nobody had yet explained. The only reason that suggested itself was, that it had an appearance of science about it. It was very scientific to say, " This is the ten-millionth part of the quadrant of the earth's circumference," and that might be the foundation for this arbitrary mètre gauge. All he had to say about it was that, apart from the question of rolling stock, the alleged saving in bridges, earthwork, and other construction, was altogether illusory. In order to obviate the objections to the narrow-gauge stock, as originally designed to meet the exigencies of military transport, the rolling stock, as now designed, was nearly, if not quite, as wide as that on the ordinary gauge. This at once disposed of a large part of the alleged saving; for, as this extra width could only be attained by making the frames overhang the rails 1 ft. $1\frac{1}{2}$ in. more than at present, much more strain was thrown on the rails, and much more wear was occasioned to the wagons. The carriages themselves involved extra cost of maintenance, which it was impossible to estimate; in fact, the width of the formation of the excavations, as well as of the bridges, both over and under, could not, in practice, be reduced below that of the ordinary gauge; so that a similarity must exist in all particulars, save that of the mere width between the rails.

Mr. Bidder would now only ask the attention of the meeting to an extract from the last report, from the able pen of Mr. Juland Danvers, made in 1872 :—

" A great deal has been said lately about the burthen thrown upon the Indian revenues by the railways, in consequence of their failure to earn the amount paid by Government for the guaranteed interest upon the capital. This result is no doubt greatly to be lamented, and is contrary to the expectations of those who advocated and sanctioned the existing system. But taking a broad view of the subject, these undertakings may claim, as a set-off against their shortcomings, credit for many direct and indirect benefits which they have produced.

" To say nothing of the moral and social improvements, which as civilizing agents, they have conferred on the country, there can be no doubt that railways have added to its security, have greatly advanced the material prosperity of the people, and have been the means of increasing the revenue and of saving much expenditure, both on account of the army and post-office. They are still in their infancy, and their direct contributions to the revenue are capable of expansion. Experience has taught us lessons, and we have paid for them; but I venture to think that there is more ground of hope for the future, than regret for the past. And as regards the present, difficulties and uncertainty should furnish a strong incentive to skilful administration and increased exertion."

With these words he entirely agreed; and he hoped the increase in the prosperity of the Indian railways, and the advantages to the proprietors, would not be arrested by the proposed introduction of a break of gauge, which could only be characterised as a calamity, as grievous, with regard to railways in India, as it had been in this country.[1]

Major-General STRACHEY, R.E., F.R.S.—being unable, on account of hoarseness, to make himself audible—handed in the following written remarks, which, by permission of the President, were read by the Secretary. He stated that he came forward in this discussion with some hesitation, and, perhaps, even with some anxiety. He felt that he appeared under great disadvantage in following some of the leaders of the Engineering profession, men whose adverse opinion necessarily carried with it great weight; and that he was addressing an audience, the sympathies of the majority of which were with his opponents. He was there, having no authority to represent the views of the Government, whose acts were in substance under discussion, but with the sense that any failure on his part to carry conviction would be attributed, not, as it should be, to his personal deficiencies, but to the cause itself. However, he was conscious that, under the circumstances of the case, it had become necessary for him to take a share in the discussion, and he accordingly did so.

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[1] Since the conclusion of the discussion it has been ascertained that on the 11th of March, 1873, a return was made to the House of Commons, signed by Mr. Thornton, containing the following extract from a Minute of the late Lord Dalhousie respecting the gauge of Indian railways:—

"Extract Minute by the Earl of Dalhousie, Governor-General of India, dated 4th July, 1850.

"32. The Court of Directors have recommended, at the same time, the use of the narrow gauge of 4 feet 8½ inches for the railway about to be constructed. Although the letter of the Court recommends, but leaves to the Government of India to determine as to the gauge which should be adopted on this occasion, I consider the question to be one of such moment as to deserve a careful consideration and an authoritative and conclusive decision by the highest authority connected with the Indian Empire, who alone can have access to that full information and extended experience which would make such a decision really and satisfactorily conclusive.

"33. The British Legislature fell unconsciously, and perhaps unavoidably, into the mischievous error of permitting the introduction of two gauges into the United Kingdom. The numerous and grievous evils which arose from that permission are well known, and will long be felt throughout all England. The Government of India has it in its power, and no doubt will carefully provide, that however widely the railway system may be extended in this Empire in the time to come, these great evils shall be averted, and that uniformity of gauge shall be rigidly enforced from the first."—*Vide* Appendix I.

Before proceeding to the more special matter in hand, he would say a few words as to the manner in which the question before the Meeting had been treated by the gentlemen who had preceded him. They had, as it appeared to him, spoken, if not with an expressed, at all events with an implied sentiment, that the Government of India should submit itself to the judgment of the Institution, or of English engineers, in respect to the course it had taken in adopting the narrow gauge in India. There had been a sort of assumption that English civil engineers were, in such a question as that before the Meeting, the fit persons not only to advise but to determine, and that engineering experience obtained in England was the only qualification of any value in dealing with the details under discussion. There had been no indication that other considerations were involved in the policy of the Government than those of a technical nature. There had been no recognition that the circumstances of India had any important bearing on the questions at issue. There had been no suggestion that persons who had passed a large part of their lives in India might be better able to judge of the wants and capabilities of that country, than those who had never even seen it. There had been no account taken of the probability that those who were responsible for the government of that country, and who alone could have at their command all the various available sources of information regarding its political, social, material, and financial condition, must be the proper persons to decide such a question as this; and that it would be a complete inversion of parts for the Government to supply its general knowledge to professional critics, and to leave to them the guidance of its policy.

He felt the highest respect for the judgment of the leading civil engineers of this country, and he assented to a large part of what had been said in the discussion by Mr. Harrison and by Mr. Hawkshaw; but he could not admit the necessary applicability of many of their doctrines to every case; and as regarded the present case he denied the applicability of much that had been said. He must affirm, as a general principle, applying to all branches of the gauge discussion, that experience based on one set of conditions was not conclusive under totally different conditions. In truth, the correct presumption, where conditions differed greatly, was, that results would also differ greatly. When, therefore, the Government of India and its advisers were more or less directly charged with want of due regard to professional considerations, based on English experience, he did not hesitate to retort, that, whatever might be the technical knowledge of the critics, they did not possess such a knowledge of Indian local conditions, or of the practical administration of a great country, as to render their opinion more than one of the elements—though an important one—in the consideration of the question. Further, he was convinced that the serious financial failure of the Indian railway system—for that it had failed financially was beyond question—had been caused by the want of subordination of European technical skill to a proper perception of local wants and resources; and the lesson that he necessarily drew from that conviction was, that the progress of railway construction in India should be brought much more completely under the control of the responsible government of the country than had hitherto been the case.

The Government of India had thus summed up the grounds on which it had resolved to adopt the narrow gauge for the railways between Lahore and Peshawur, and Mooltan and Kotree:—"We are satisfied that the economy likely to be obtained from the adoption of the narrow gauge will justify our accepting the break of gauge at Lahore, with such inconveniences as it involves." This, he believed, quite fairly stated the case. That certain inconveniences might be caused by a break of gauge was not denied, but the advantage to be secured, by economy of construction was said to be such as to justify the conclusion come to.

The Paper under discussion had for its object the elucidation, from the Author's point of view, of the facts on which such a conclusion might be supported. The reply that had been given to the Author, by the gentlemen who had already taken part in the discussion, had been directed to the object of showing that on the Author's data the saving of money by the adoption of the narrow gauge would not by any means amount to what had been represented in the Paper, and, in fact, that it would be insignificant; while the objections to the break of gauge were little short of insuperable.

Now he would at once recognise that the Author's adversaries had, at all events, some appearance of success in their criticism of the first part of the Author's argument; namely, that which related to the supposed superior economy of the narrow-gauge system. But this advantage was not substantial, and, so far as it had gone, had been gained over the Author's way of stating his case, and in no way disturbed the essential conclusion affirmed by the Government of India.

Before going on to state the grounds on which he rested this remark, he thought it would be desirable for him to show what was likely to be required of an Indian narrow-gauge railway, and to what extent it would be able to meet those requirements. If the mètre-gauge lines, as now being constructed, were not fully able to carry all the traffic likely to be brought upon them, the whole argument in their favour would be at an end; but he would show how questions on that point might be met.

It had been ascertained that the total traffic of the East Indian railway, the heaviest worked line in India, might be taken to be about equal to 840 tons of goods, and 1,064 passengers, carried over every mile of railway in 24 hours. Also, it had been found that, taking the combined passenger traffic and goods traffic, the average load of an East Indian train was about 71 tons of goods, together with 89 passengers, which, for the present argument, might be considered as carried in a mixed train.

Supposing, further, the passengers to be equally divided between the up and down traffic, and the goods to be carried in the approximate proportion that actually held in the two directions, about 6 trains, such as he had described, in both directions, would suffice to do the work.

Now if a narrow-gauge railway, such as those actually under construction at the present time in India, were set to carry this traffic, it would be found that the load of an average East Indian train could be conveyed in about 14 narrow-gauge wagons and 3 narrow-gauge passenger carriages, of the pattern now being supplied—that was supposing all the wagons and carriages to be run full. If the vehicles were supposed to carry only half their full loads, double the number of such trains would be required to that actually run on the East Indian line. Such a narrow-gauge train as he was speaking of would consist of, say, 18 vehicles, including a brake-van, and, if full, might weigh in the gross 144 tons. With vehicles half full the load might be about 100 tons. One of the 12-ton engines recently made for the Indian narrow-gauge lines would suffice to draw such loads on the ordinary easy gradients of Indian lines.

Hence it followed that the whole traffic of the East Indian railway, as now existing, might be carried on a line of narrow-gauge railway, with an average of 12 trains a day each way, such trains running half empty. As such a condition of things could not possibly be necessary, and as 2 engines could be combined, or 18-ton engines and 24-ton engines could easily be provided if desired, there could be no room to doubt that the narrow-gauge lines, as now being constructed, and doubled when necessary, were quite capable of carrying the heaviest traffic now existing in India, or ever likely to be brought on them.

The narrow-gauge wagons and passenger vehicles were quite able to carry what was required, whether merchandise, or military equipments, or stores—the heaviest siege gun with its carriage did not weigh 5 tons—or that was or could be carried on the 5 ft. 6 in. gauge; and the only real difference between the gauges in that respect was, that more vehicles were required on the narrow gauge than on the broad gauge, to contain a given weight of goods. Under these circumstances it seemed quite opposed to fact to speak of the mètre-gauge lines as 'toy' railways, or as being weak with reference to the actual traffic to be carried on them.

Having, as he believed, thus fully established the sufficiency of the narrow-gauge lines under construction for all that was required of them, he would discuss the question of their cost as compared with that of broad-gauge lines.

It was first essential to inquire whether the estimates, that had up to the present stage of the discussion been referred to, properly represented the cost of the railways that would have been constructed between Lahore and Peshawur, and between Kotree and Mooltan, if, on the one hand, the narrow gauge had been adopted, and on the other, if it had not. To this inquiry only one answer could be given, namely, that those estimates were utterly worthless for the object in view; that they did not in any way represent the financial consequences of the alternative systems of construction, and that the conclusions of the Government of India were not based upon them or anything like them.

The Author, giving what might be termed a logical turn to his argument, had endeavoured, and General Strachey thought with complete success, to show that even on the figures which had been put forward by the opponents of the narrow gauge in the present case, an important pecuniary gain would have been secured by the adoption of the narrow gauge. Rejecting those figures as wholly inapplicable, General Strachey asserted that the financial advantage, that had in fact been secured, was very great, and that it would fully justify the conclusion that had been come to by the Indian Government.

The estimates referred to were based on a 40 lbs. rail for the narrow gauge, and a 42 lbs. rail or a 45 lbs. rail for the broad gauge, and, so far as he could judge, corresponding loads for the bridges, thereby implying that the alternatives between which the Government had really made a selection, were lines thus to be designed. He denied this emphatically. It was certain as a matter of fact, which he challenged any one to disprove, or even to question with a show of reason, that if the broad gauge had been adopted the rails would not have been lighter than 60 lbs. to the yard, and that the general characteristics of the lines and the stock, engines, as well as vehicles, in use on the neighbouring broad-gauge lines would also have been accepted, and that all the bridges would have been designed to carry the heavy loads of that gauge, instead of the reduced loads of the narrow gauge.

He was at the present moment stating what would have been, as distinguished from what might have been, and he positively asserted that the question which the Government of India had to decide was this:—" Shall we accept a narrow gauge with all possible economy, subject to such inconveniences as a break of gauge at Lahore involves; or shall we preserve the continuity of gauge, and provide for the free passage of the stock of the existing broad-gauge railways to meet possible military exigencies, by the adoption of the broad gauge in its existing form for the lines to be made on the Punjâb frontier?" The idea of a compromise between the two plans which should give some of the advantages, while it had some of the disadvantages of both, did not appear to meet the real question at issue, and did not come seriously under the consideration of the Government.

As a fact the construction of the Lahore and Peshawur line had actually been begun on the broad gauge before the question of adopting the narrow gauge was raised, and 100 miles of 60 lbs. rails were ordered, and the original designs of the bridges were prepared on the regular broad-gauge standard of strength.

For these reasons it seemed to him to be placed beyond dispute, that the actual saving that would be obtained, by the adoption of the narrow gauge in the Punjâb, could not be reckoned at a smaller sum than from £1,000 to £1,500 per mile on account of permanent way, and from 30 per cent. to 40 per cent. on the cost of the iron-work of all bridges, besides minor economies of various sorts, into which it was needless to enter in detail.

For the Lahore and Peshawur line, on a length of 270 miles, the saving on permanent way would amount to about £350,000, and on the bridges perhaps to £250,000, or together £600,000. On the whole he considered that the total economy might be about three-quarters of a million. The 490 miles of the Indus Valley railway would give a saving of not less than £500,000 on the permanent way, and probably as much more on other items, or, in all, about one million; but the character of the works was not yet sufficiently known to admit of any very precise statement being made as to this line.

Against the savings thus attainable must be set off the cost of

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the first change from the broad gauge to the narrow gauge on the line between Lahore and Peshawur, and the outlay necessary for obviating a break of gauge between the new narrow-gauge lines and the existing broad-gauge lines from Kurrachee to Kotree, and from Mooltan to Lahore.

It was not now possible to estimate that charge in a definite way, because it had not yet been determined what arrangements should be made at the junctions between the new narrow-gauge lines and the old broad-gauge lines. Taking the most unfavourable view of the case, it seemed impossible to suppose that a greater outlay than £500,000 could be necessary; which would still leave a total advantage on the Punjâb lines of about £1,000,000.

Those figures did not take into consideration the greater economy of maintenance on the narrow-gauge lines, which would probably be in proportion to their greater economy in first cost. It was difficult to estimate that element of saving at present with any useful amount of precision; nor did he think that account of it could properly be taken in this discussion, as it did not concern the capital outlay. Mr. Hawkshaw, however, had reckoned it to be equal to the whole saving on the first cost of the permanent way, and on this standard the additional amount to be credited to the narrow-gauge lines would be more than three-quarters of a million, thus raising the whole saving to about two millions.

But he readily admitted that he did not attach any particular weight to the exact amount thus arrived at. What he desired to affirm was that there seemed complete evidence of a very important saving, due to the adoption of the narrow gauge; and that the only countervailing disadvantage, the break of gauge, was not one which would, under the actual circumstances of the traffic, render the saving illusory or nugatory.

So far as the interests of commerce were concerned, he entirely agreed with the Author that a single break of gauge at Lahore between the lines down the Indus Valley and up to Peshawur, and those leading to Delhi and the eastward, might be altogether disregarded. Even the double break that would be caused by the interposition of the mètre gauge between Kotree and Mooltan, if no change whatever were made in the existing broad-gauge lines, he should regard commercially as of little importance. The cost of the transfer of goods would be very much more than compensated by the reduced interest on the capital saved. It was not in the least to the point that a break of gauge in England, under circumstances of a totally different nature, had been found to be intolerable. To complain of the injury done to the traffic on the

Indus Valley railway because vehicles started from Delhi, for instance, would not be able to pass to Kurrachee, would not be less visionary than a similar complaint as to interchange of traffic between Russia and Spain. No tendency to any such traffic could arise that would have the smallest practical importance.

As to the railway from Lahore to Peshawur, it was equally visionary to anticipate any export traffic except of the smallest amount. There was hardly any cart traffic in the districts west of the Ravee, and beyond the Jhelum that sort of conveyance was impossible, except along the line of road now to be occupied by the railway. As to the import trade from the west, the one item of any importance would be salt. Now the retail selling price of salt in the districts of the North-Western Provinces, where the more important consumption took place, varied from 3 rupees to 4 rupees per maund, or say from 160 shillings to 200 shillings per ton. If the cost of transfer at Lahore, from the narrow-gauge wagons that brought it from the mines to the broad-gauge wagons that carried it on to the markets for it in the east, amounted to 4*d.* per ton, the result would be an increase to the retail price of no more than from $\frac{1}{6}$ per cent. to $\frac{1}{8}$ per cent., a quantity quite inappreciable. If any one thought 4*d.* per ton too little for the cost of transfer, he could readily correct the calculation; but the most extravagant estimate would not raise the charge to 1 per cent. on the selling price.

He was somewhat at a loss to follow Mr. Hawkshaw's remarks as to the necessary evil of break of gauge apart from the extent and nature of the traffic; and such extreme doctrines as that gentleman appeared to advocate struck him as little less ludicrous than an assertion, that the original cost of loading goods into wagons rendered railway transport in all cases commercially impossible, because this might be true in some extreme case.

As to the effect of the break of gauge on possible military operations in the Punjâb, he agreed entirely with the Author. To argue on this point from any experience obtained from military operations in Europe, without a careful discrimination of the features which would be alike and different in any possible war on the Punjâb frontier, could lead to no conclusions of any value. He should not attempt to enlarge on the possibilities of war in India, or to imagine the circumstances under which troops or military stores might have to be moved by railway in that country. All that he need say was, that the narrow-gauge lines under construction would be as efficient in the transport of troops and stores, within the practical necessities of the case, as any broad-gauge line that could be made, without going to an expense vastly in excess of anything that had ever been seriously suggested.

A single line of railway, having very severe gradients for a considerable part of its length, could not be regarded as an efficient instrument for moving large bodies of troops, accompanied by horses and guns, and the other impedimenta of an Indian army; and this was equally true of a 5 ft. 6 in.-gauge as of a mètre-gauge line. On the other hand, as far as the supply of stores was concerned, the narrowest-gauge line ever constructed would readily meet all the demands of any army that was ever likely to be put in the field on the Punjâb frontier.

It was not to be supposed that he denied the general advantage of continuity of gauge and the corresponding disadvantage of break of gauge—very far from it. If the 5 ft. 6 in. gauge could have been retained consistently with other necessities of the case, no one would ever have proposed a change. Now what were the facts? Having provided about 5,000 miles of railway, the country found itself burdened with an annual payment of one million and three-quarters in respect of those lines, in excess of all receipts, and with little prospect of any early or considerable relief from this heavy financial burden. Further, it was apparent that under the existing system of construction and management, it could hardly be expected that any more railways could be made without leading to a permanent charge on the revenues of from 2 per cent. to 3 per cent. on the whole capital outlay required. It was under these circumstances that the Government of India, seeing the great importance of the extension of railways, determined to seek some more economical system under which this extension might become possible. The conclusions come to were, that all lines should in the future be carried out without the intervention of companies, and that the outlay on construction should be reduced to a minimum, by the adoption of the narrowest gauge and the lightest rails and rolling-stock, compatible with the requirements of Indian traffic.

Now it was not to be supposed that so serious a change could be made without strong opposition. It would also be apparent how the two parts of the policy of the Government—the suppression of the companies and the change of gauge—were almost necessarily bound up together, particularly in the outset, and with respect to those districts where existing companies supposed they had claims to carry out suggested extensions. The success of the new policy of the Government depended on its being applied on a large and consistent plan; and any hesitation in applying it on the first occasion on which it seemed likely to be productive of decided economy would very possibly have led to its total miscarriage. It could not be admitted that the economy likely to be obtained by the new policy of the Government would be limited to the saving of first cost on the new lines of railway, though this alone would fully have justified it. The economy due to the change of system of management must not be lost sight of as an essential part of the plan. Therefore, in order to estimate the whole financial advantage of the new policy in the Punjâb, a question of great complexity had to be dealt with, which, though it related to engineering operations, involved grave considerations of financial and political importance, and thus became one of general administrative policy.

The responsibility for coming to a decision on this question rested with the Government of Lord Mayo and the Duke of Argyll; and their decision was in favour of the system of construction which the Indian Government began to carry out about two years ago.

It might also be observed, that the course which the Government of India had thus felt itself compelled to adopt, was that which other poor countries had also lately adopted in many other parts of the world where, as in India, capital could only be obtained from foreigners and on an absolute guarantee of interest, and where the traffic prospects were poor. The recent development of narrow-gauge railways in the southern parts of the United States of America showed that the experience of that great commercial country was not in opposition to the adoption of cheap lines of railway, involving break of gauge, under certain conditions of traffic and first cost.

Although there were many other developments of the subject which might have served, in his own opinion, to strengthen his argument, he felt that he should not be justified in further intruding on the patience of the Meeting, except in relation to one or two matters from which the course of his argument had gradually led him away.

First, as to the proposals that had been made, that broad-gauge lines should be constructed with light rails, say from 42 lbs. per yard to 45 lbs. per yard, in preference to lines of a narrower gauge.

He had said, in relation to the Punjâb lines, that the alternative did not, in fact, arise; but the objection that existed in that case would not necessarily apply in others. If required to state shortly his own conclusions on that point, he should say that the narrower gauge necessarily possessed a certain amount of financial advantage; and that if 45 lbs. rails or 42 lbs. rails were suited for wagons carrying 16 tons on 4 wheels, such as those of the broad gauge, a far lighter rail would suffice for wagons carrying, on the same number of wheels, only half that load; and that the assumption by the advocates of the light broad-gauge lines that the narrow-gauge lines must have 40 lbs. rails, was untenable, and their comparative estimates based on that assumption worthless.

Further, he concluded that the presumption, in such a country as India, would be in favour of a narrow-gauge line, if the length of it was such as to justify a break of gauge, having regard to the probable traffic; or if, from the nature of the case, there was an obligatory break of gauge, caused by a great river virtually impassable, or by some other physical obstacle. For short isolated branches for broad-gauge lines, a broad gauge would still be essential.

He considered that for Indian traffic there was a decided and substantial advantage in the use of the smaller vehicles of the narrower gauge, and that this advantage would be greater in proportion to the smallness of the traffic.

At any time the doubling of a narrow-gauge line would give an almost indefinite expansion to its carrying capacity—as referred to an Indian standard—at an additional cost that would be small; and long before the carrying power of a single line was exhausted, the interest on the capital outlay would be covered, and it would have become financially productive and able to pay for its improvement.

Next he would say a word as to the manner in which these proposals to adopt light broad-gauge lines had been brought forward. Until the Government of India announced its intention of carrying out narrow-gauge railways, as the only apparent means of obtaining cheap railways, none of the Engineers of the Indian lines —exclusive of the Oudh and Rohilkund Company and the Indian Tramway Company—suggested the construction of light or cheap lines, or admitted that they were possible. Long after the necessity for reducing the cost of Indian railways had been strongly asserted by the Government, the projects and estimates prepared by the engineers of the guaranteed lines continued to maintain their old character. Without going back to the history of the first-constructed broad-gauge lines (or even of those which, like the Delhi and Lahore line, served to bring the Government to adopt its present railway policy), it would be found that the latest project for the broad-gauge line along the Indus Valley, which had been superseded by the narrow gauge, was to have cost more than £11,000 per mile. The proposed lines in Rajpootana were set down at from £12,000 per mile to £14,000 per mile. A line projected between the two branches of the Great Indian Peninsula Railway was estimated at £12,500 per mile, and rejected by the Government as financially impossible, without any proposal on the part of the engineers that it could be constructed for a smaller sum; and this list could be extended. He stated without hesitation that in all those cases the corresponding cost of a suitable narrow-gauge line would not exceed £7,000 per mile, and might be less.

He made no complaint on that score; but he drew attention to the fact, that it was now asserted that those lines might be made on the broad gauge virtually as cheaply as on the narrow gauge, and that this remarkable change of opinion was coincident with the announcement of the change of the policy of the Government.

So that the Indian Government might congratulate itself on the happy conclusion that, whatever might be the waste which, according to its opponents, would accompany the adoption of the narrow gauge, its adoption had, at all events, had the effect of opening the eyes of the broad-gauge engineers to possibilities of economy in the construction of such lines, of which they before had no conception.

Mr. G. B. Bruce said they were much indebted to General Strachey for having stated so fully, so clearly, and so fearlessly his own views upon this important matter; and knowing, as they all did, the part which General Strachey had taken in India in connection with this case, it was extremely important they should have from him a clear and explicit statement of his own views, and the grounds for the conclusions at which he had arrived.

With regard to the first statement in his communication, in which General Strachey said this Institution seemed to think the Government ought to be guided by the opinions of the Civil Engineers, he had assumed, in the first place, that the gauntlet was thrown down by the Institution or by those who, like Mr. Bruce, held it was a mistaken policy to introduce a break of gauge. This was not the case. The discussion was introduced here fairly and fully by a conspicuous member of the Indian service—holding a high place at the India Office—bringing a Paper before the Institution; therefore, when that Paper came to be discussed, the Government must not be surprised, and he thought this Institution was not liable to blame, when it was found the discussion turned almost entirely upon purely technical questions. There were good reasons why it should do so. The Author had based his arguments entirely upon technical grounds. He told them that "the one solitary reason of the Indian Government for adopting a narrow gauge was belief in its superior economy." He did not say one word about policy, or about the blindness of men who had not been in India to understand Indian affairs, but he confined himself simply to the question of cost. To that point Mr. Harrison, Mr. Hawkshaw, and Mr. Bidder had applied themselves, fairly and properly, because it was strictly within, and did not go beyond, the limits of the Paper.

They were told that the smallness of the traffic was a good reason why there should be a narrow gauge. He thought General Strachey was about twenty-five years too late in telling them that. The question now was, not to fix a gauge for the first time, but whether, having made 5,000 miles of railways on a certain gauge they were to introduce a new gauge, and whether the saving thus effected would compensate for the evils which were admitted to be inherent in a break of gauge. Therefore smallness of traffic was not the question, unless it could be shown that the difference of price was very considerable. It was stated that the question which had to be decided was, not whether there was to be a light broad gauge, but a light narrow gauge or a heavy broad gauge. Now, Mr. Bruce thought if the Government authorities, finding themselves in difficulty as to how these railways would be constructed cheaply, had allowed others to suggest how it could be done, he was satisfied some mode of doing so would have been fully laid before them; and as to anything that could be said against making the wider gauge with light rails, and working it with light rolling-stock, Mr. Harrison had told the meeting that the standard gauge in this country was for years laid with light rails, and was for years worked with light rolling-stock. Thirty years ago some engines were put upon the Grand Junction Railway which were objected to on the ground that they weighed a little more than 16 tons, which was less than the weight of the proposed Indian narrow-gauge locomotives. The engines he alluded to had for a time worked the great traffic of this country, and it would be easy to use the same kind of engines on the ordinary standard gauge of India. General Strachey however assumed, that with the wide gauge they must necessarily have heavy engines, and therefore they were obliged to have heavier rails on the broad gauge than on the light; and then he suggested the question, Why did not you gentlemen suggest that these rails should be laid so in the first instance? Mr. Bruce had some experience of Indian railway economy, and, generally speaking, it had not been, at least so far as regarded the Govermental bodies, satisfactory; in fact, there was a decided dislike in all large bodies like a Government to allow anything to be done out of the ordinary way; and if the suggestion to lay down a portion of a line with 40 lbs. rails, as now proposed, had originally been made, the reply probably would have been, "We don't see the use of it; do as you have been doing hitherto."

General Strachey had stated that the narrow-gauge line could be made for £7,000 per mile. Mr. Bruce thought some Members of the Institution had constructed railways on the 5 ft. 6 in. gauge for that amount per mile, or even less; therefore there was nothing new in the proposition. It had been done already by gentlemen then present; in fact, he had done it himself on a line not far distant from the sea; although the question of transport of the rails was not a serious item. He did not recollect the price of the rails, but that would affect both cases in the same way.

He had carefully followed the remarks made by General Strachey, and he would especially guard himself against appearing to be the opponent of any gauge. He believed in all gauges, and he thought every wise man did the same; and where it was found, as in the cases alluded to, in many of the colonies and in other places, that the narrow gauge had been selected, and it had been carried out largely, he would as much oppose the introduction of a wider gauge to interfere with the uniformity of the narrow gauge as he would in India oppose the introduction of the narrow gauge to interfere with the broad gauge. The principle he held was this: That in a country which had decided upon a particular gauge, and which gauge was to a considerable extent carried out, it was extremely unwise to alter it, because the difference in cost was so trifling as compared with the disadvantages of a break of gauge. In some cases it might be a question of railway or no railway; and no doubt there were instances where a small saving might present that alternative. That was not the case in India, and there was no difficulty in finding money for the construction of railways there.

It was stated that 4*d.* per ton represented the money value of a break of gauge. He would like to ask Mr. Grierson whether 4*d.* per ton, or anything like it, or even whether any money value could represent the disturbance of traffic? if it had done so, the Great Western would have continued to allow the large traffic to go past them, as they had done for a quarter of a century, to be carried by their neighbours? It was not merely money value; it was the disturbance of traffic, which they could not estimate at 4*d.* per ton, or any other sum.

Apart from local questions, with regard to the Punjâb, the Author appeared to have based his statement of an alleged saving of

£1,000 per mile by taking the estimates of Mr. Hawkshaw and Mr. Fowler, and adding to them items which one or other of those gentlemen repudiated. He had not before him Mr. Hawkshaw's estimate, but, with regard to Mr. Fowler's estimate, there were one or two points to which he would draw attention. First, Mr. Fowler's estimate was a comparison between a 5 ft. 6 in. gauge and a 3 ft. 6 in. gauge. He gave a width of embankment for the wide gauge of 14 ft., and for the narrow gauge of 10 ft. 6 in.; that was, he made the embankment 3 ft. 6 in. wider for a difference of 2 ft. in the gauge. He should like to know what was the object of that? There was no sense in it. Then, as to sleepers, Mr. Fowler gave a sleeper of 8 ft. 6 in. for the wide gauge, and of 6 ft. 3 in. for the narrow; again, a difference of 2 ft. 3 in. for an increased gauge of 2 ft. He thought there was no sense in that. Then, again, with regard to ballast, Mr. Fowler told them they must have a depth of 9 in. of ballast under the sleepers of the wide gauge, and of 6 in. under the sleepers of the narrow gauge. Mr. Bruce maintained it should be exactly the other way—that it was more necessary to have the road good on the narrow than on the broad gauge. He would instance in the one case a broad-gauge carriage, and in the other a narrow-gauge carriage, each having one of the rails under it depressed to the extent of 2 in. The deflection of a rail to that extent on a narrow gauge would throw the carriage over into a position of danger, whereas such a deflection on the broad gauge would simply make it a little oscillating in its motion. That being the case, it was the more necessary to have the road well ballasted and supported on a narrow gauge than on a wide gauge; therefore, if any difference was made in respect of the depth of ballast, it should be exactly the reverse of what had been now proposed.

It so happened that just now 216 miles of mètre gauge were being constructed in the south of India. He had obtained the estimates of the line, and had examined them, to see what would be the increased cost of making it on the broad-gauge system. This was not a mere supposition, but a fact. The earthwork would come to £33 per mile additional; the ballast to £27 10*s.*; sleepers, £99; that was including freight to India, and carriage. The sleepers would cost 9*d.* each more; the iron girders would cost £10 per mile more. The girders for the larger spans were designed to carry the road on the tops of cross girders, and were 5 ft. 6 in. apart. There would be nothing to do but to move the longitudinal bearers out, so as to be immediately above the girders, and to widen the platforms, and the extra masonry for that would cause an increase of £10 10*s.*

per mile. Mr. Bruce put land at the same price as the Author, namely, at £10 per mile, though Mr. Harrison showed it was more like 10s. per mile. That made a total difference of £190—say £200—per mile, or, on 216 miles, of £43,200, as the total absolute saving of cost upon that line; and, supposing the line just paid its working expenses, the 5 per cent. guarantee would be £2,160 a-year; or, taking the normal condition of the railways as a whole—that they earned 3 per cent., and the Government had to make good the other 2 per cent.—it would cost the Government, or rather the unfortunate ryots, of whom so much had been said, £864 per annum to avoid break of gauge in that district of India. Applying this fact to the 10,000 miles assumed by the Author, how did it work? It would be a saving of two millions, and, taking 2 per cent. there again, that represented a saving to the Treasury of India of only £40,000 per annum, against which they had to put all the disadvantages of the break of gauge, which it was impossible to calculate; and he was certain, on facts like these, there could be but one decision in this Institution. He had left out of that calculation the additions of agencies and engineering, which, he thought, was shown by Mr. Harrison, did not require to be considered at all, because it would virtually be the same. He had likewise left out the £200 per mile added for curves, because they knew that, in ninety-nine cases out of one hundred in India, in the matter of such curves as they required, they would not save anything at all. He had also omitted the £10 per mile for maintenance, mentioned in Mr. Hawkshaw's report, for two reasons; in the first place, it was not first cost, and, in the second place, if they went into maintenance they must take the other side of the ledger, namely, what it took to maintain rolling-stock of that description; a much wider stock, and altogether a less mechanical stock, than the railway companies were in the habit of using, the increased maintenance of which might very soon occasion a loss of much more than £10 per mile.

The Author based his Paper entirely on the difference in width of gauge; he had left out of consideration the width of carriages. Mr. Bruce maintained that width of vehicles was a truer test of cost of line than the width of gauge. When an ordinary mètre-gauge carriage, constructed according to the Government regulation, was contrasted with wagons on the 5 ft. 6 in. gauge and on the 4 ft. 8½ in. gauge, it would be observed that, in the latter two cases, the journals came directly under the top bars, leaving proportionately little overhang in the wagons. Nobody could persuade him that by the mere moving in of those wheels, in the case of the mètre gauge, while the wagons themselves were kept wide, the railway could be made any cheaper. The ordinary gauge of a carriage like that for the mètre gauge would be about 4 ft. 2 in. to render it an equally mechanical construction as those on the wider gauges.

A great deal had been said about economy in working, which, he supposed, was based upon the old idea of the difference in weight of stock. He had given attention to that point, and he made out, that if the gauge was widened from 3 ft. 6 in. to 5 ft. 6 in., supposing the wheels to remain the same, as they were not an element of the gauge, the weight of the wagon would be increased about 4 cwts.; and supposing the weight to have been 50 cwts. originally, the weight would be increased by 8 per cent., and the capacity by 24 per cent.; and the increase in width of the carriages would add 11 per cent. to the weight, whilst the capacity would be increased 24 per cent.: so that, so far as the element of gauge was concerned, there was nothing to be said, on that question, in favour of the narrower gauge. It might be true that the wagons and carriages were built a little too heavy, but that was not an element inherent in or dependent on the gauge. The only allusion to the working of the line was made by General Strachey. Mr. Bruce's own impression was, that a most fallacious and absurd stress had been laid upon the cheapness with which a narrow gauge could be worked; but he was prepared to waive that point, and not to take it into consideration in either case. A great deal had been said about the lines not paying; and they were told by the Author that it was only a reasonable supposition that the rates and fares of guaranteed railways were fixed with a view to the production of the largest revenue. He did not think Mr. Grierson would concur that he was free to develop the traffic of the Great Western Railway, to the fullest advantage for the shareholders, if the Board of Trade, in addition to their present powers, had the fixing also of the number of trains per day, the time of leaving and the time of arrival, as well as the rates and fares both of passengers and goods. No doubt these were fixed by the Government as much as possible for the interests of the State, not of the shareholders; but he knew, without going into the matter at length, many Indian railway managers demurred to the idea that the traffic was worked to the best possible advantage; therefore there was good reason for supposing that the railways had not reached their maximum, or that they had got all the trade they would have, if the lines were worked on commercial principles. There was no ground, therefore, in the present smallness of traffic for reverting to a narrow gauge. The Author stated that it was all very well to send their broad-gauge wagons on to these light broad-gauge lines, and that in the event of war they would get a good supply of wagons, but they would not get engines. They knew very well they could not run broad-gauge engines over 40-lbs. rails at high speed, but in an emergency they could run those engines slowly, yet effectively; and those who understood how contractors ran heavy engines over light rails would see that on an emergency it could be done in India, and the whole broad-gauge stock of the country could be made available at any point, in case of war. It might be said—and was partly said by General Strachey—that if these lines could be made so cheaply as was stated, it was a pity it had not been already done. Mr. Bruce thought the reason why these lines were to be made cheaply, whereas the others had been made comparatively expensively, was because there was a different code of rules drawn up in the one case and in the other. He might mention, in the case of the Madras railway, he wanted to build his stations with low platforms. The Government thought it desirable to have high platforms. He argued, what was good enough for England was good enough for India; but they would have high platforms: consequently the expense of the stations was increased in every way. That showed the tendency had been to make everything on a colossal scale, whereas the governmental ideas now tended in quite the opposite direction. The true medium was perhaps just half-way.

He would venture to repeat that he thought the Government of India having made 5,000 miles of railway, and having the means of making as much more on the same gauge as they liked, almost as cheaply as on the narrow gauge, it would be the worst possible policy to construct those lines on the narrow gauge. He was perfectly certain—and he was confirmed in what he had said—that the difference of amount was less than £200 per mile. He was confirmed in this opinion by a letter from a Chief Engineer in the south of India, in which he stated his belief that £200 per mile was the whole amount of saving that would be effected by the change.

Mr. Carl Pihl said he was not prepared to make any remarks upon the Paper in reference to the general issues which had been raised as regarded the railways of India, as he considered there were not only technical, but also military and political considerations involved, with which, as a stranger, he felt himself incompetent to deal. But having had ten years' experience in the construction and working of the narrow gauge in Norway, he could state that all parties felt it answered the purpose there, and the narrow-gauge lines had been built considerably cheaper than those on the broad gauge[1]. It was owing, no doubt, to the cheapness of construction that Norway was indebted for even such railways as she had. The traffic had not yet reached the present capabilities of the railways, so that he did not see why, under similar circumstances, a cheap system of construction should not be adopted. There was also a line of railway of 4 ft. 8½ in. gauge about 100 miles long in Norway, and they were about to make another 100 miles. The length of the narrow-gauge lines was about 200 miles, and another little line of 40 miles was to be made. With reference to the difficulties and disadvantages of a break of gauge, of course he could draw no comparison between the circumstances of such a line as the Great Western and those which existed in Norway, where they had no such circumstance as the narrow gauge competing in the same districts with the broad gauge; and in such a state of things no one could question the wisdom of abolishing the exceptional gauge, and substituting the uniform gauge of the country; and that being done, the most important question was the disposition of the rolling-stock of the broad gauge; but the adaptation of it to the narrow gauge was a much easier task than that of expanding narrow gauge stock for adaptation to the broad gauge.

There were at present in Norway about 100 miles of broad gauge, and 100 more expected to be constructed; whereas of the narrow gauge there were about 200 miles in operation, 200 miles under construction, and about as many more in contemplation. In Norway a break of gauge between a narrow gauge of about 300 miles and a broad gauge of 42 miles in length would have to be encountered, but in that case it was justified, as the inconvenience of a break of gauge by no means balanced the economical advantages which arose from the adoption of a cheap line for so great a length. Though fully impressed with the inconveniences of a break of gauge, he considered that question to be one that in all cases had to be weighed in connection with the gains expected from the change. He could therefore not see the justice in bringing forth the experience from the Great Western as a warning instance in every case, for there was no comparison between the circumstances of such a line and those in Norway, or other countries similarly situated. Under such a state of things as existed on the Great Western Railway of England, no one could question the

[1] *Vide* also ante, p. 247, foot note.

wisdom of abolishing the exceptional gauge and substituting the uniform gauge of the country. In this case it should not be lost sight of, that in that instance it was an already existing broad road that had to be changed for a narrower one. That in itself was a matter of no very great expense. It was the dealing with the rolling-stock that was the real difficulty, but in that the directors of the Great Western railway had no doubt for a long time been prepared, and the change was no doubt facilitated, and its expense lessened, by its being carried gradually into operation in successive portions of the Great Western railway system.

Mr. C. D. Fox said the Institution was indebted to the Author for bringing forward, in this open arena of discussion, a question which had hitherto been too much confined to pamphlets, and in which, as it appeared to him, two very different subjects, namely, that of gauge and that of light or heavy construction, had become mixed up. Comparisons had been made between the cost, both of construction and of working, of different railways, from the Great Western railway of 7 ft. 1 in. gauge, to the Festiniog line of 1 ft. 11 in. gauge; and, on reading some of the arguments put forth and purporting to be based upon such comparisons, one gathered that the difference of cost depended entirely upon the gauge. The absurdity of such a notion need not be commented upon.

With reference to the general question of the gauge of railways, it was evidently impossible to lay down an empirical rule. He would venture to suggest that, if an engineer was to do his duty properly, he must have no foregone conclusions on this or on any other question, his duty being to investigate the circumstances of each case, and to apply his experience to those circumstances in the best possible manner. Thus, if it was a question of high speed and heavy traffic, he thought it would be agreed that the English standard gauge of 4 ft. 8½ in. was in every way suitable. It appeared to him a fact much to be regretted that in India, in Canada, and in several of the colonies, and also in Ireland, a wide gauge should have been adopted. The agitation for a narrower gauge would probably hardly have arisen in connection with India, had the standard gauge been the same as in England. But whilst the English gauge was well adapted for its purpose, there were countries and districts in which it was very important to keep down the cost, and, in doing so, where circumstances had not rendered such a step undesirable, he had found it advantageous to adopt a narrower gauge. For instance, in the colony of Queensland the 3 ft. 6 in. gauge was adopted for the Government railways, 220 miles in length, with which he was connected, and it had proved a great success, but in that instance the question of break of gauge was not involved. In Canada likewise, the same gauge had been adopted, under his advice, for 250 miles of railway running from Toronto. In that instance break of gauge had to be considered, but the circumstances were of a special nature. On the one hand the standard gauge was 5 ft. 6 in., and on the other, it was of the greatest importance that the new line should be made with great economy; and when he spoke of economy, he was not dealing with such an amount as arose in the case of the Indian railways, but with a question of a few hundred pounds per mile. It was found that £3,000 per mile could be raised from the resources of the country; but that, if the cost came to £3,500 per mile, it would be impossible at that time to construct the railway. It was therefore necessary that everything should be done to keep down the cost to the smaller amount. The population of the country was very thin, and there was no military question involved—for, instead of running up to a frontier which was threatened, as the northern frontier of India was, by a neighbouring state of great military power, these lines ran from a populated centre on the great chain of lakes up to the backwoods, the object being to open up the country, and to carry population where it did not exist, and in that way to add to the commercial resources of the district. With regard to the Government railways of Norway, also on the 3 ft. 6 in. gauge, he had already laid before the Institution[1] a description of their salient points, and, in justice to Mr. Carl Pihl, the Engineer for the Norwegian Government on that line, it must be stated that it was he who, long before the question of a narrow gauge had been brought prominently forward, had worked out in very complete detail a system of railways economical yet efficient, and thoroughly adapted to the requirements of that country.

He considered that these and other railways of the 3 ft. 6 in. gauge had demonstrated very completely the efficiency of that gauge, when it was adopted under suitable circumstances; but it would, nevertheless, in his opinion be most injudicious to introduce either that, or any other gauge differing from that of the main lines, in cases where the standard gauge was of moderate width, where the branches to be constructed were comparatively short, where

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xxvi., page 49.

the traffic was likely to be considerable, or where through communications were important for military purposes.

This led him to make a few remarks upon the subject of a break of gauge, upon which a great deal had been said, based upon the experience of the Great Western Railway Company. He quite agreed with the remark of Mr. Pihl, that the prejudicial effects of a break in the gauge of a system of railways must be measured by the special circumstances of each case. These effects must be serious where lines were short, where time was valuable, and where, as in England under the admirable arrangements of the clearing house, rapid interchange of rolling-stock was possible, and still more serious, when, as in the case of the Great Western, a railway suffering from a break of gauge was exposed to severe competition for through traffic from powerful rival lines having but one gauge throughout, or when, as in India, the military question had to be considered.

Such a break of gauge, however, became less important when it only occurred once in a large system; and in cases where time was comparatively of small value, where no military question arose, and where exchange of rolling-stock was from the great length of the lines practically impossible, or of very rare occurrence. And on this last point he would venture to state what had been the experience of some of those who had had to do with the interchange of rolling-stock in America. It so happened that, until lately, three lines, belonging to different companies, but of the same 5 ft. 6 in. gauge, met at Toronto, in Canada, and yet the inconveniences attending the exchange of stock were so great, that there were very few instances of the cars of one company being sent over the lines of the other companies. If a wagon were thus sent, it was probably not seen again for weeks. The General Superintendent of the Erie railway, a large and important system, wrote thus:—" I confidently believe that the experience of railroad managers generally will bear me out in the remark, that a road 500 miles in length, with a gauge that does not correspond with that of any independent line with which it connects, enjoys in this particular an enviable position."

Even in this country the return of empty wagons had become a serious matter, so much so indeed, that the North Eastern and other companies in England were discouraging as much as possible the use of private wagons on their lines. It would be interesting to know to what extent wagons were run through without breaking bulk on the 5,000 miles of uniform gauge now existing in India.

Mention had been made of the alteration of the gauge on a considerable portion of the Great Western system in England. A similar process had been in action on the Great Western railroad in Canada, and on a portion of the Grand Trunk lines, where the gauge had been altered from 5 ft. 6 in. to 4 ft. 8½ in., and on the Ohio and the Mississippi railroad, which had been reduced from 6 ft. to 4 ft. 9 in. It was worthy of notice that in each case the change had been from a broad to a narrower gauge. In the United States, where there were more than 50,000 miles of railway of the 4 ft. 8½ in. or of wider gauge, lines of the 3 ft. gauge were now being largely introduced in localities where great economy was necessary. He, however, believed that it would have proved more satisfactory had the gauge for these lines been fixed at 3 ft. 6 in.

The capacity of the 3 ft. 6 in. gauge was a question upon which he desired to say a few words, as it appeared to him there was some misconception upon the point. He had read a very elaborate argument against the narrow gauge, based upon a maximum width of wagon of 4 ft. 9 in. He also understood that the designs for the Indian State railways were based upon a maximum width of only 6 ft. 6 in. This latter was the width adopted for the Queensland railway, but the experience there gained had enabled him to go as far as 8 ft. 6 in. in width on the 3 ft. 6 in. gauge in Canada, and on these railways the traffic was carried by rolling-stock of which the following were examples: —Passenger cars upon the American system, 31 ft. long, 8 ft. 6 in. wide, and carrying 38 passengers. Freight cars, some 15 ft. long by 8 ft. wide, carrying 12,000 lbs., others 30 ft. long by 7 ft. 6 in. wide, carrying 20,000 lbs. Locomotives on 6 wheels, coupled, and a leading bogie, cylinders 14 in. by 20 in., weighing 26 tons, exclusive of the tender, and hauling 250 tons upon gradients of 1 in 60 at speeds of 15 miles per hour; tenders carrying a cord of wood and 1,000 gallons of water. This stock had been found to work steadily, smoothly even at high rates of speed, and round curves of 5 chains radius. The traffic in Canada consisted largely of logs and sawn timber, flour in barrels, grain, and cattle; and in Queensland, of wool and cotton, articles similar to those which would be carried in India.

On the 5 ft. 6 in. gauge, it was found practically unnecessary to adopt any stock wider than 8 ft. 5 in., although, so far as safety was concerned, the width might have been increased to 11 ft. Thus it happened that, dealing with things, not as they might be theoretically, but as they were, the narrow-gauge stock of

Canada was almost identical with the broad-gauge stock of India, as regarded the height from the rail to the top of the roof, and absolutely so as regarded width, the centre of gravity being, however, lower in the former than in the latter case.

It appeared to be of great importance, in view of the character of the traffic in India, that the stock should not have a less width than 8 ft.; but he thought that a width of 8 ft. 6 in. would be preferable.

He considered it very undesirable, except under special and exceptional circumstances, to adopt a gauge of less width than 3 ft. 6 in. Upon this gauge, experience had proved that locomotives could be constructed with fire-boxes large enough to produce good results; but every inch of diminished width in an engine, having, as usual, the fire-box limited by the distance between the wheels, would tend to seriously cripple its power.

With reference to the cost of working, having had considerable experience of the 3 ft. 6 in. gauge, he could state distinctly—as, indeed, common-sense would lead any person to expect—that there was no appreciable difference between the cost of running a train or of hauling a ton of goods on the 3 ft. 6 in., on the 4 ft. 8½ in., or on the 5 ft. 6 in. gauge. Supposed examples to the contrary, which had been largely made use of in arguments in favour of extremely narrow gauges, might readily be shown to be entirely illusory, and it was much to be regretted that the subject should have been surrounded with statements which could not be borne out in practice. There was, of course, a considerable saving in maintenance on a light narrow-gauge, as compared with a heavy broad-gauge railway; but if the rolling loads and the weight of rail were made, as they might be, the same on both gauges, the difference would become hardly appreciable.

As regarded the comparative cost of the broad gauge and of the narrow gauge, he would remark, that this would vary greatly according to circumstances, but he believed that the practical difference would be greater than the theoretical difference, as the saving had been found, in fact, to pervade every department. In Canada, the cost of the 3 ft. 6 in.-gauge lines, complete in every respect with the exception of rolling-stock, had been £2,800 per mile, the rails weighing 40 lbs. to the yard; whilst a railway of 4 ft. 8½-in. gauge, with rails weighing 50 lbs. to the yard, and running through the same district, had cost, in like manner, exclusive of rolling-stock, over £4,000 per mile. In Queensland, owing to the heavy nature of the works on the Main and Liverpool ranges, there could be no doubt that the adoption of the narrow gauge, and the system of construction accompanying it, had resulted in a very large saving. In India, however—where the larger proportion of the country had very little inclination, and much of it was perfectly flat; where the chief works consisted of bridges of great length, the piers of which must in any case be strong enough to resist floods, and the girders of which would be much more affected by rolling load than by gauge; where the embankments must be wide to resist the heavy rains, and where ample ballasting was, in either case, essential,—the difference of cost of a light line on the broad or the narrow gauge was certainly reduced to a minimum.

The principle of introducing a lighter mode of construction on the standard gauge having been determined by legislation in England in 1868, the Carnatic Railway Company entered into a contract with the Secretary of State for India, early in 1870, for the construction of their line upon the standard gauge, with rails weighing 45 lbs. to the yard, and having works so designed as to take all the rolling-stock of the existing lines, excepting the locomotives. Some progress was made, and locomotives were prepared from Mr. Fox's designs, for the 5 ft. 6 in. gauge, having no greater weight on a wheel than 4 tons, such being the maximum weight on any of the existing wagon or carriage-wheels. Since, however, the question of the adoption of the mètre gauge had arisen, further progress in this direction had been suspended, and fresh surveys and estimates were asked for by the Government, based upon the mètre gauge. There could be no doubt that a considerable saving, both in first cost and in maintenance, could be effected, without any alteration of gauge, by reducing the weights upon the driving wheels of the engines to the same as those of the other stock; and, especially in India, where high speeds were not generally required, and sharp curves were rarely necessary; and that this could be attained, without materially reducing the power of the locomotives, or introducing any abnormal types of construction. This being done, the weight of permanent way, and of the superstructure of bridges, could be reduced almost as much as if the narrow gauge were adopted. The reduction might be quite as great, were it not that, in designing stock for a light broad-gauge railway, it must be made suitable for running intermixed with existing stock, and of withstanding the heavy shocks of shunting and the higher speeds of the main lines, and also that the permanent way and bridges must be strong enough to bear the existing stock. Were a narrow gauge adopted, central buffers could be introduced, the weight of the under-frames be reduced, the centre of gravity lowered, and the rolling load be brought down to about 3 tons per wheel, with a proportionate diminution of weight and cost throughout. If, in order to avoid a break of gauge, light broad-gauge lines were introduced, some precaution, either mechanical or legislative, would be essential to prevent their being used by the heavy locomotives of the existing lines, and to regulate the speed of the trains. In England he had found it practically impossible to make use of the light system, as the main line companies insisted, where they were to work the branch, that it should be so constructed as to take not only their rolling-stock, but their heavy locomotives; but in India, the Government, having the control, could avoid a difficulty of that kind.

Having thus briefly remarked upon the general principles arising out of the discussion, he would desire to say a few words upon their special application to the case of India. One could hardly look at the map before them, especially the upper part of it, having in view the fact that the proposed lines in North-Western India derived their chief importance, not from commercial, but from political and strategic considerations, without feeling that—even if the saving of first cost, claimed by the Author, should result from adopting the narrow gauge between Kotree and Mooltan, and between Lahore and Peshawur, narrowing the Scinde railway to the mètre gauge, and introducing the mixed gauge between Mooltan and Lahore,—all which he ventured to doubt,—the break of gauge at Lahore must prove most serious, not to say suicidal, in a military point of view. The Government, through the Companies, had provided itself with 5,000 miles of railway on the 5 ft. 6 in. gauge, bringing the more important military centres into direct and unbroken communication with Lahore. It was now necessary, in order to protect the frontier, that the system should extend to the port of Kurrachee on the one hand, and to Dadur and Peshawur on the other; and it did appear to him that, unless this were effected on the broad gauge, so that the existing rolling-stock—and even the locomotives at low speeds—might pass freely to the frontier, the chief value of these extensions would be lost. He could not but regard with disfavour the proposal to introduce the mixed gauge on a system of this kind; for, having had some experience of it in connection with one of the metropolitan termini, and elsewhere, he could bear testimony to the complications and inconveniences which accompanied its use, and which would, in his opinion, render it in the present case an evil only second to that of a break of gauge. As regarded the Punjâb, then, the case seemed to him to be most clearly in favour of the broad gauge, unless—which he had not heard suggested—the Government contemplated the reduction of the existing system of railways to a narrow gauge.

If there were any such intention, he would certainly hesitate to select as the standard so narrow a gauge as that of the French mètre, or to permit, for the purposes of the Indian traffic, the reduction of the width of rolling-stock below 8 ft.

As regarded many other parts of India, the question appeared to be different; and in Mysore—and on the proposed line to Carwar especially—it might perhaps be found that sufficient economy would result from the adoption of a narrow gauge to justify a break of gauge. In the case of the Carnatic railway, the estimate showed—even through the level country of that district—a saving of fully 20 per cent. by the introduction of the mètre gauge, and a very light construction, as compared with such a broad-gauge line—lighter than the present main lines which the Government were then prepared to sanction—and such a saving was important, at any rate in the interest of a railway company, if not in a national point of view. He however believed that, if the Government permitted all the economy which was practicable, still retaining the standard gauge, the difference of cost might, owing to the character of the country, and the large number of bridges which would not be affected by the gauge, be reduced to some such insignificant amount as that referred to by Mr. Bruce; and he certainly felt that any such saving ought not to be allowed to influence the decision of so weighty a question as that under discussion, fraught as it was with momentous consequences as regarded the future welfare of the Indian Empire.

Sir G. B. Airy, P.R.S., Astronomer-Royal, remarked that, after the able critical examination which had been made of almost every engineering point, with regard to the proposed system of railways in India, it was not in his power to throw any additional light upon that branch of the subject; but there was an important, and, perhaps, the most important part of the question, on which he might speak. He was a member of the Royal Commission appointed in 1845, to consider the question of the break of gauge, and which made its final report in 1846. The question of the break of gauge was then beginning; in fact, there was only one place where the two gauges at that time actually met, and that was at Gloucester. The Commission did their best to examine into the whole state of things at the one break of gauge, and as to the probable state of things that might ensue. They studied the working of the traffic at the Gloucester station; they obtained the best evidence; they examined Mr. Brunel's ingenious contrivances; and the conclusions at which they arrived, and of which they felt the correctness very strongly, were these:—In the first place, that there must be no such thing as a break of gauge,—that it was absolutely necessary that one gauge should run all through the kingdom;—and they thought it desirable that this should be the narrow, or 4 ft. 8½ in., gauge. But there had been much discussion on what could be done on railways of different breadth, upon which they had not sufficient evidence at the time. The Commission recommended that attention should be given to the possibility of the admixture of gauges; but that at all events the first principle should be carried out; and in a subsequent letter addressed to Sir E. Ryan, the Astronomer-Royal individually urged the same thing more strongly, and especially that attention should be given to the possibility of working a mixture of gauges; for the Commission held it to be important that liberty should be given as far as possible, and that Mr. Brunel's contrivances, admirable in many respects, should not be driven out of the field without receiving further trial. The Report of the Commission was strongly attacked, in pamphlets and in newspapers, by the advocates of the broad gauge, and finally it was resisted so strongly in the House of Commons that it was thrown out. He had watched the progress of events since that time with some interest, and he found it was this; that the Great Western railway, which naturally was the most strenuous opponent of the Report in the first instance, at length adopted precisely what the Commission recommended with regard to the gauge; trying first, the mixed gauge, and afterwards abandoning the broad gauge entirely, substituting for it the narrow, or 4 ft. 8½ in., gauge, which was now universal throughout the kingdom. And he could not help recollecting that amongst the representatives of the broad-gauge system there was one who especially commanded the respect of the Commission; that was the present Chairman of the Great Western Company, who was then the locomotive-superintendent, and was very strenuous indeed in his support of the broad gauge; but, nevertheless, the Commission felt it necessary to express an opinion opposite to that which that gentleman held; and even he had been driven by the force of circumstances to take the course which was recommended in the report. After this the Astronomer-Royal need not say his own feeling against the break of gauge in India, or anywhere else, was very strong indeed; and looking, not so much at the recommendations which the Commission made, as upon the course which events had forced upon railway companies, it did seem to him an act of most extraordinary imprudence to introduce a break of gauge in India.

There was one point which he omitted with respect to the break of gauge, and it was this:—Numerical estimates had been given of the inconveniences of the break of gauge, and it was stated that goods might be transferred at from 8*d.* to 1*s.* per ton. Now he apprehended such a statement as that could only apply to goods on a large scale, such as bags of cotton, or rice, or barrels of flour, or articles of that character; but it could not apply, he thought, in any degree to mixed merchandize; and still less would it give the slightest idea of the injurious effects if a break of gauge occurred in the transport of an army, or of its munitions. As to having a stock of carriages of one gauge ready to meet a stock of carriages of another gauge, he looked upon such a proposition as an absurdity, and it had been so regarded, in an instance which preceded the Commission on the gauge question, on the Eastern Counties railway. The circumstances were these:—A short railway, which was likely to have communication with the interior of the country, and was 4 ft. 8½ in. gauge, was amalgamated with a longer railway upon a wider gauge. Upon that amalgamation taking place, the Directors of the amalgamated company immediately saw they could not go on under the existing state of things, and they at once changed the gauge of the rails and the working stock of the longer railway to suit those of the shorter line; and upon that no doubt depended the efficient existence of those railways. That was an instance, he would state, showing the impossibility to provide what was necessary upon one railway by the stock meeting it upon another railway. But with regard to the break of gauge in India, he would say he conceived it was impossible to provide a rolling-stock upon one railway which should be always ready to meet that upon another gauge; and from the evidence before the Gauge Commission, as well as from ordinary observation, there could be no doubt that the difficulty of a break of gauge in military matters would be extreme. India had not been held in subjection by the governing classes of Great Britain in the same way as England or Scotland; by the sword it had been gained, and by the sword it must be held. And however much legislation on behalf of that country might recognise the desirability of studying the welfare of the natives of that country, it must be remembered that there was a spirit of independence generally at work, and there were parties ready at all times to stir up internal tumults; while at the same time there were those outside who, at the proper time, would be ready to invade. It was necessary, therefore, to be prepared to make rapid movements of armies. With the means of rapid communication to the frontier of

Peshawur, at the opening of the Khyber Pass, it would be a question whether it was necessary to maintain so large a garrison there; and the advantage of landing troops without the fatigue of marches—especially in India—was too well known to admit of any question.

Adverting now to the question of the width of gauge as applied to India, he conceived there was not that objection to the wider gauge which some eminent men appeared to entertain; but as between the entire adoption of that gauge and of the change of gauge the difference was very great indeed. Amongst the objections which might be raised against the narrow gauge, he conceived there was one of considerable importance with regard to military matters. It would be difficult, he thought, upon the narrow gauge to carry field artillery except in a dismounted state, and it would be very troublesome to carry horses; and it was to be considered that the carriage of a large number of horses was indispensable in military matters. Even with infantry regiments the officers must be well provided with horses; and to carry horses at any speed on the narrow gauges which were proposed, he thought would be a very hazardous matter. With regard to the alleged difficulty of adopting a wider gauge which would arise from the windings of the railway, he did not think there was anything in the nature of the country to make that an obstacle. There could scarcely be anything worse in that respect than the Todmorden Valley railway, and the trains ran very well on that line; and, generally speaking, he should say, upon any railway where the speed was well understood, and where the rails were not over-canted—which he looked upon as an essential condition—the form of the conical tires used might be made so to guide the wheel frame of the carriages that there would be no sensible friction produced by the difference in the length of the inner and outer rail. These were mechanical points which he did not feel himself authorised to urge so strongly as he did the question of the existence or the non-existence of a break of gauge; and he repeated this opinion very strongly as the result of all he had heard and seen. Therefore, he thought it would be most injudicious to have a break of gauge in the Indian railway system, and he was only surprised to find that the existence of such an evil had ever been seriously entertained.

Captain Douglas Galton, R.E., C.B., said, that having been officially connected with the system of railways in this country, during a part of the gauge controversy, and especially during the controversy on the mixed gauge, he was glad to have the opportunity of offering a few remarks upon the question. He thought it would have been an intelligible policy on the part of the Indian Government to have introduced on to the Indian railways the 4 ft. 8½ in. gauge, and to have altered the whole of the existing lines to that gauge; because, in the event of any great evil happening in India, it would have enabled rolling-stock to be shipped at a moment's notice to replace the destruction of stock on Indian railways; but the Indian Government had already 5,000 miles of railway on a standard gauge traversing the country in all directions, and, under these circumstances, he considered it undesirable to introduce a second extensive network of railways upon a mètre gauge, mixed up with the 5 ft. 6 in. gauge, and forming breaks of gauge on numerous main lines of communication. It was expedient, no doubt, in some cases, to adopt a very narrow gauge to bring down the produce of mines, or factories, or quarries, at a cheap rate to the main line of railway, so as to avoid any transhipment of material at the quarry or the mine; such lines should be cheap tramways for locomotives, which were cheaper to construct and maintain than ordinary roads; and in such cases, each arrangement required special separate consideration; but in this case it appeared that the railways which were proposed to supplant the whole of the existing standard system would, according to the estimates of independent persons, not effect a saving of more than from 6 per cent. to 12 per cent. This would not have been an intelligible course of proceeding had it not been for the explanation of General Strachey, who, he believed, stated, that in the comparative estimates which he submitted to the Indian Government, he had assumed the cost of the standard gauge according to the then standard requirements of the Indian Government, and the cost of the narrow gauge at a new standard of light railway, as proposed by him. They were met in this discussion by being told that they were not conversant with the customs of India, and therefore they were unable to appreciate the effect of a break of gauge in India. He thought if this mode of making comparative estimates was the custom of India they would all agree with him they were not accustomed to it. Now with respect to the question of the cost of these railways it had been so ably discussed by other speakers, that he thought it scarcely necessary further to allude to it, except that no sweeping estimate of this character could be a fair one. Each line required to be looked at separately, in regard to traffic and construction.

As to the question of sidings, the Gauge Commission, in 1846, laid down the axiom that whatever improvements could be introduced on the narrow gauge could be introduced with much greater efficiency on the broad gauge; therefore in comparisons between the carrying powers of the two gauges, it must be admitted that the weight carried per wagon must be in proportion to the gauge; therefore, a train of forty carriages on the broad gauge would carry an amount of goods equivalent to what seventy carriages would carry on the narrow gauge, and consequently the sidings on the narrow gauge must be longer than the sidings on the broad gauge, in the proportion of 7 to 4; and as the cost of the platforms and other accessories of loading would increase in proportion, he thought, instead of estimating the cost of sidings as a proportion of the cost of the railway, it should rather be taken in the inverse ratio of the cost of the railway.

Passing on to the question of the break of gauge, the Author said the cost of transhipping goods at Lahore would be about £850, and he capitalised that at a sum of £17,000. He put the cost of transhipment at 4*d.* per ton, and, as he must be supposed to be well acquainted with the cost of labour in India, that was a figure which they might accept; but there was another important element in the cost of transhipment of goods, that was the injury to the goods. The evidence before the Gauge Commission placed that at 2*s.* 6*d.* per ton, but he would not urge that figure. He would only deal with the one article which the Author and General Strachey both made mention of as being the principal article transhipped at Lahore, namely, salt. Now Captain Galton happened to have some connection with the salt districts in this country, and he had made it his business to inquire of some of the largest manufacturers of salt, in the Midland district, as to the amount of damage to that article from transhipment; and Mr. John Corbett, the manufacturer, who had the greatest experience as to the break of gauge in the transmission of salt, put the amount at 1*s.* per ton, where the value of the salt was 30*s.* per ton; but the cost of the damage necessarily varied with the value of the salt. General Strachey had stated that the value of salt in India varied from 160*s.* to 200*s.* a ton, therefore the Author's figure of £850 would, upon this estimate, rise from £850 to at least £16,000, and his capitalised sum of £17,000 would rise to between £300,000 and £350,000. So much for the commercial question; and with respect to the military point of view, General Strachey seemed to imply that the military question was perfectly immaterial. Now, in the report of General Strachey, Colonel Dickson, and Mr. Rendel, addressed to the Indian Government in September, 1870, they laid great stress upon the military question, and the Author devoted two pages of his Paper to the same point; therefore he thought it evidently was one which at all events the Indian Government considered as important. Now, he did not think the Author, or General Strachey, had quite appreciated what was the effect of railways upon the movements of an army. The railway enabled them to dispense with forming large magazines near where the army was operating; it enabled them to draw supplies of every sort from almost unlimited distances, and it also enabled them to remove from armies those impediments to their movements, the wounded soldiers, whom otherwise they would have to provide for and to protect. All, who had seen them, admired the excellent arrangements made by the Germans, during the Franco-Prussian war, for the supplies of their army in France. He happened to have been connected with the National Society for Aid to the Sick and Wounded, and he made an expedition along the rear of the German army and saw in detail the arrangements they made for the supplies of the troops. The main feature of those arrangements, and the main thing which enabled them to work with so much smoothness and facility, was the means which they adopted for loading their trains. Each train was specially appointed to a particular division or section of the army, and each train was so loaded that it should convey a portion of all the supplies likely to be wanted. so that if the train itself broke down, or even if a portion of the train broke down. still some portion of the supplies would, at all events, reach the army. Now, he left them to consider what would be the effect of such a mode of arranging their trains and packing their vehicles with a break of gauge. They would have in the first place to change the supplies which had been carefully arranged in a train of forty wagons into a train of seventy wagons; and at the time they were doing this they would have brought down upon them trains of wounded men, some of them incapable of moving hand or foot, who would have to be transferred across the same platform and placed in another train. He was convinced that any one practically conversant with the transhipment of goods or with the loading of trains for ordinary military purposes, would admit that the confusion of such a proceeding would be indescribable, and he thought they would also agree that no money saving could compensate for such a fearful crisis as would then arise. In the matter of the conveyance of the wounded, the Prussians were able to carry four or five wounded men on spring beds with a nurse to attend upon them in a large goods wagon. Now, he did not think any carriage they could place on the narrow gauge would enable them to carry more than two wounded men with a nurse. If they admitted the axiom that the same improvements could be introduced upon the broad gauge as upon the narrow gauge, it must be assumed that the carrying capacity of the carriages were in proportion to the gauge. Therefore, if they could carry more on the mètre gauge, then they would be able to accommodate proportionately more on the broader gauge; but he felt sure that General Strachey did not appreciate what a large space was required for severely wounded men on a long railway journey. They would, moreover, have to increase the number of nurses, at all events, in proportion to the number of wounded men, and that at a time when every available man was wanted to assist in the warlike operations. General Strachey stated in his observations that one object in introducing cheap lines on the narrow gauge and not estimating cheap lines on the broad gauge at the same time was the difficulty of controlling the expenditure on Indian railways. That seemed to Captain Galton a most astonishing statement, because he had always understood that every detail of construction of Indian railways was submitted to the department of Public Works, over which he believed General Strachey presided, and not only the details of construction, but even the number of trains was fixed by that department. General Strachey also put down as part of the economy, the alteration in the arrangements for constructing lines, that is to say, the construction of the lines under the Government instead of under companies.

Now he thought it would be a digression here to enter into the question as to the economy of Government construction and management of railways as compared with the commercial principle, but he would only say that was not an element that could be fairly imported into this question, because, whatever system could be adopted upon one class of railway could be equally adopted on the other, seeing that the details of construction were in both cases under the direct control of a Government department. In conclusion he must say it was much to be regretted, that the Indian Government, in arriving at a decision on this matter, had had placed before them reports favouring what seemed to be foregone conclusions in the minds of the gentlemen to whom the question was referred, and which reports omitted material facts which would have been adverse to such conclusions. He was glad the question was coming before the House of Commons, and he trusted after the light which had been thrown upon it by this discussion it would be remitted back to the Indian Government, and that they would then arrive at a more satisfactory conclusion with regard to it.

Mr. H. Lee Smith said he had devoted much time to the subject, upon which, perhaps, he could give the meeting information that was not generally known; but he was unaffectedly reluctant to monopolise needlessly one minute of its time, which would presently, he hoped, be more profitably employed in listening to more valuable and authoritative opinions. In proof of his sincerity, he would pass very hurriedly over the fact that his figures, as given in the Paper, were painfully misquoted. His estimates for the standard gauge were quoted thus:—

For the Peshawur line	£3,712,440
„ Indus Valley line	3,895,631

But in these sums the Author had, by mistake, no doubt, included two large items on account of maintenance for three years, namely, £85,050 and £128,790, together £213,840, which, being deducted, made the total amount of saving not £912,479, but £698,639. The Author had also entirely omitted to remark that Mr. Lee Smith's estimate for the Peshawur railway on the standard gauge was for an independent line, with banks and cuttings of its own; whilst his mètre-gauge estimate was for a line laid, with the exception of the salt branch, on the metalled road. But what Mr. Lee Smith might have previously said or written on the subject was of little consequence; his present object was to endeavour to meet the Author upon his own ground.

With that part of the Paper which related to the importance of economy, few persons would be disposed to quarrel; the doubtful point was whether the government of India had not adopted altogether too violent a remedy, the effects of which, in the long run, would prove worse than the original disease. It was, however, with the proof of economy, set up by the Author, that they had to deal, and there it was that he appeared to have fallen into error. The Paper literally bristled with fallacies, which Mr. Lee Smith would divide into two classes, the special, and the general; the first having reference solely to the Punjâb lines; the latter—the general fallacy—being the assumption that even if, in the case of some particular line, a saving of £1,000 per mile could be established, the same would hold good over 10,000 miles.

On the Peshawur railway, for example, as half of the metalled road was given up to the line, it would be obvious that the first two items of saving claimed in the Paper, namely, land and earthwork, were entirely illusory.

Mr. Lee Smith had long held the belief that the reduction of the gauge was accepted under some very exaggerated idea of the saving to be effected by the change. Lord Lawrence had stated that, "the average estimated cost of the guaranteed lines was about £17,000 a mile," and the late Lord Mayo had also endorsed that statement. At the same time there were many rumours flying about of "highly-efficient narrow-gauge lines—the railways of the future," at a cost not exceeding £4,000 per mile or £5,000 per mile. Now although he did not mean to argue that either of the eminent statesmen he had named could ever have supposed that any feasible reduction of the gauge would result in a saving approximating to £12,000 per mile, still it was very remarkable to observe the apparent effects of such statements and such rumours upon the minds of some of the foremost men of India.

In a Minute, entitled "The Earl of Mayò as Viceroy of India," Sir John Strachey, a leading Member of Council, reverted to the subject thus:—"The average cost of our guaranteed Indian railways has been about £17,000 a mile. Lord Mayo was satisfied that it was impossible to go on making railways in India at such a cost. He said we must have cheap railways, or none at all; and he strongly supported the proposal that, in constructing new lines the old broad gauge should be abandoned; that, if it were held to be obligatory that the Peshawur line should be constructed on a broad gauge, it would be the duty of Government to say that it could not incur so great an expenditure; whereas the adoption of a narrow gauge would lead to a very large economy." Sir John further stated that, "although he could not enter into these discussions, they were conducted on both sides with great ability."

Now although there might not be any actual proof deducible from this, still, from the expressions "at such a cost," and "so great an expenditure," it did seem a little like a jump to the conclusion that £17,000 per mile, or thereabouts, was the price of a standard-gauge line, and that no expedient could be devised, or, at least, had been thought of, for diminishing that price, save the one mentioned in the very same breath, "the adoption of a narrow guage would lead to a very large economy."

From this he would only argue the probability that narrow-gauge lines, as compared with those on the standard gauge, were at first accredited with a reputation for economy to which they had not been able to, and could not now, substantiate a claim; that in this manner they obtained almost an unfair hold, and were allowed to take firm root, whilst the death of Lord Mayo left the matter in a somewhat false position, that of a question fairly argued out to the end and irrevocably decided. As for Sir John Strachey's statement, that the question was argued on both sides with great ability, had he said, upon one side, it would surely have been nearer the mark; for, with exception of Mr. Hawkshaw's prophetic warning, which was sent along with the Committee's report, to the Government of India, there did not appear to have been a single protest lodged against the reduction of the gauge or a counsel engaged, or witness called to speak a word in defence of the standard gauge.

They now heard of the two divisions of a narrow-gauge railway up the Indus Valley, described by the consulting engineer to the Government of India as 'a surface line,' and estimated to cost (exclusive of one or two large bridges) about £5,100 per mile to £6,000 per mile—average, £5,550 per mile, or, deducting rolling-stock, say £5,000 per mile. Was this considered a great result? Was breaking the gauge the only expedient by which this figure could be come down to? Why, even in his poor Indian practice, Mr. Lee Smith had done much better than that! He had before him the 'completion statements' of a district of the East Indian railway, 81¼ miles long, of which he had responsible charge. It was executed 'departmentally,' that was without the aid of large contractors, and had cost, taking the whole length, £6,160 per mile; but as 37¼ miles of this were constructed under the heavy troubles and disadvantages of the great Mutiny, he thought he might fairly cut them out, and speak only of the remaining 44 miles, which were commenced after the Mutiny, and finished in fair time — three years, he believed, or as fast as they could get the permanent-way materials. The cost of this division was exactly £5,370 per mile, which included earthwork, ballast, bridges and culverts, level-crossings, permanent-way, telegraph, stations — including the fair proportion of a large locomotive-changing-station in the centre of the division—everything complete, except land and rolling-stock. He had also added—not knowing the precise amount—10 per cent. on account of Engineering expenses. Some of the rails weighed 78 lbs. per yard, and some 82 lbs. per yard. He did not now remember which were used upon this particular division; but assuming the lighter and they had this section of the main line of the East Indian railway—with which, on the score of stability, no man need be ashamed to have been associated—completed, upon the 5 ft. 6 in. gauge, with 78-lbs. rails, for £5,370 per mile, against the estimated cost of a mètre-gauge surface line up the Indus Valley, with 40-lbs. rails, at £5,000 per mile. Nor was there any advantage owing to proximity to the sea; the land-transport was not less than 800 miles; that was up to the neighbourhood of Agra. And if General Strachey wished to know the price of the rails—though Mr. Lee Smith regretted being unable to state precisely—he believed it could not have been very much below that quoted lately by the consulting engineer to the Government of India for state railways, for his 40-lbs. rails, namely, £8 per ton free on board in England. Mr. Lee Smith almost forgot to mention, as being perhaps worthy of note, that the embankments of the standard-gauge line, of which he had given the details, were 34 ft. wide at formation-level, instead of 10 ft. 3 in., the estimated formation width of the Indus Valley line.

But no English Engineer, however great his experience, could, with any propriety, have volunteered his opinions in the face of the following Resolution by the Viceroy in Council, in accordance with which, Mr. Lee Smith believed, some American Engineers were specially invited to India. He would not read the whole of the decision, unless it was their wish, but content himself with the following extract:—"The time has come when India should cease to lean exclusively upon English Engineers in dealing with its railways."

Here he might perhaps be permitted to remark, that he felt it a little ungenerous on the part of his friend General Strachey that he should have included him in his censure, or at least not exempted him from his criticism upon the Engineers of the Indian lines, who never "suggested the construction of light or cheap lines, or admitted that they were possible." General Strachey might perhaps have forgotten that, as Secretary to the Government of India in the Public Works Department, he had sent Mr. Lee Smith in his own handwriting the flattering assurance that "Government was perfectly satisfied with the Chief Engineer of the Peshawur line, who had cordially and loyally accepted the general policy of the Government;" which then, as now, Mr. Lee Smith understood, not as a tribute to his unvarying good behaviour generally, but as an acknowledgment that he was devoting all his poor energies to contriving how to carry out his work to the best advantage of Government. The reduction of gauge was then unthought of. It was suggested to him for the Peshawur line by an amateur; but if it had been seriously proposed to him by Government, he would then, as now, have given his decided opinion, supported by his reasons, that it was wholly unnecessary, and extremely unwise. To say that he did not think of or suggest light permanent ways, was a mistake. Seven years ago, in his first Report on the Peshawur line, he stated that, although 50-lbs. rails "might be equal to the present (then) requirements of the traffic, experience had proved there was no real economy in reducing the rails below the ordinary standard, and that, in his judgment, the heavier permanent way would prove the better economy in the end;" an opinion of which at the present day he was not greatly ashamed.

These, however, were trifles hardly worth mentioning. The serious part of General Strachey's remarks was that wherein that officer referred to figures. Was it not almost time for some powerful remonstrance, when they found the highest, nay, the only Indian State railway officer in this country, who inaugurated, and still alone led the way in the break of gauge, two years after that step had been taken, talking in this strain:—"Those estimates were utterly worthless for the object in view." "Rejecting those figures as wholly inapplicable, General Strachey asserted that the financial advantage, that had in fact been secured, was very great." "The saving on permanent way would amount to about £350,000, and on the bridges perhaps to £250,000, or together £600,000." "On the whole he considered that the total economy might be about three-quarters of a million. The 490 miles of the Indus Valley railway would give a saving of not less than £500,000 on the permanent way, and probably as much more on other items, or, in all, about one million." "But," he added, "the character of the works was not yet sufficiently known to admit of any very precise statement being made as to this line." Fortunately Mr. Lee Smith had the precise information, in the shape of the latest estimate by the officiating Chief Engineer, given in the most minute detail, from which Mr. Lee Smith, at least, had been able to arrive at somewhat less vague results. He would state the exact additional cost of making the permanent way of the Indus Valley railway fit to carry both the carriages and the engines of any, or all the other Indian lines. This he had worked out, to decimal parts of a rupee, from the prices given in an estimate sent to the Secretary of State by the Government of India, no further back than November last, and if they would divide General Strachey's £500,000 saving by two, and add £690 to the result, they would get the actual saving within a few shillings.

As for the bridges on the Peshawur line, he was in a position to speak from facts which he would defy any person to contradict. He himself had designed the girders for that line for both gauges, both standard and mètre, and had personally superintended all the details of the drawings down to the smallest rivet. Had General Strachey forgotten, when he talked about a saving of 30 per cent. to 40 per cent. on the cost of the ironwork of all bridges, that the smaller girders for the first 100 miles of the line were designed, constructed, and sent out of the full standard-gauge strength? Had he also forgotten that the larger bridge girders upon the mètre gauge which had been made and shipped were not narrower, nor so narrow, but—from having to carry a common road carriage-way in addition—actually 18 in. wider between the hand-railings than those which he had approved and passed in Simla and Calcutta for the standard gauge? But, not to enlarge too much upon this point, he would simply inform the Meeting that he had made at least a dozen or eighteen different designs for the bridges in question upon three different gauges, and of every conceivable span, striving in every possible way to cut down the quantity of ironwork to the lowest limit compatible with safety; that he had still in his possession all his sketches, figures, and quantities, and that if they wished to know the exact saving between the standard-gauge design and the mètre-gauge one adopted, constructed, and shipped, they must again take some liberty with General Strachey's figures. It was not 40 per cent., it was not 30 per cent.; but if they would divide the latter figure by ten they would then know exactly what the saving was. He would challenge investigation. The drawings were quite open to the inspection of any one who would seriously take the trouble to question his statements.

No one, however, who read the published official documents could entertain much doubt that the Government of India had made up its mind to the break of gauge, and accepted the necessity of it as a foregone conclusion. Looking for one moment at the facts. The question was formally referred to a committee, and a special subject or theme was set for them upon which to base their report, namely, the Indus Valley and Peshawur railways, and this theme, indeed, was still further narrowed to the former of these lines alone—the Indus Valley—as Government admitted the exceptional case and position of the Peshawur line in these words:—"We have no hesitation in saying that were it a question of the section between Lahore and Peshawur alone, we should at once dismiss from consideration all idea of anything but a standard-gauge line." But although the result of this committee's deliberations, read in the light of the Secretary of State's orders for the alterations of the Scinde and Punjâb railways, were such that any schoolboy who added the figures together could have seen, at a glance, that the proof of economy had broken down, was there any re-consideration or hesitation? Apparently not the slightest. The Government of India would seem, as he had before surmised, to have looked upon the economy as a foregone conclusion, and to have proceeded calmly to break the gauge—in spite of Mr. Fowler's dissent, and the failure on the part of the rest of the committee to prove any appreciable saving—as they alleged:—"We are satisfied that the economy likely to be obtained from the adoption of the narrow gauge will justify our accepting the break of gauge at Lahore, with such inconveniences as it involves."

Here he would beg to explain, for the information of those who might not have seen the Report which he quoted from, that by Mr. Fowler's estimate the difference of cost between making the two lines, he was alluding to, upon a gauge of 3 ft. 6 in.—that was $2\frac{5}{8}$ in. wider than that now adopted by the Government of India—inclusive of the alterations ordered by the Secretary of State, and completing them upon the standard gauge with 42-lbs. rails, amounted to £17,668 in favour of the latter. And to check this roughly, he would take Mr. Thornton's figures:—Indus Valley line, 493 miles × £1,000 per mile = £493,000 saving. Alterations of Scinde and Punjâb lines (ordered by Secretary of State, estimated by Messrs. Strachey, Dickens, and Rendel), £520,000 loss. Saving £493,000: loss, £520,000. Balance, still in favour of the standard gauge, £27,000. Were such results, emanating from such authorities, even if wildly erroneous, not worthy of searching investigation? Were they not almost startling enough to induce Government to pause before crippling for ever those two lines, admitted to be "of as great strategical importance as any yet to be made in India?" But granting, for the sake of argument, that the Author's figures were quite correct, that the reduction of the gauge between Kurrachee and Peshawur would save altogether £530,000, he would show at what real sacrifice, nay peril, this saving was to be effected.

The line, it would be observed, was cut off, absolutely shut out, from communication with any other line in India, and must, therefore, rely entirely upon its own resources in the matter of rolling stock, which ought, therefore, to be provided on a scale of unusual and extraordinary liberality. But instead of this, incredible as it might appear, the stock was actually estimated at the miserable rate of one engine and thirty vehicles for every thirteen miles, which the advisers of the Government of India stated to be calculated for, and to be sufficient for, two trains a day each way. Now, he cared not by whose testimony they elected to decide—Mr. Thornton's or General Strachey's—for by either of them he would show that these calculations and arrangements were fallacious, if not almost unfair to the policy and judgment of the late Viceroy, who agreed to the break of gauge, on, they might assume, the plain and obvious understanding that his narrow-gauge line was at least to be able to stand by itself, or, in other words, to be stocked upon such a scale as would meet his estimate of any possible emergency.

It had been said by Lord Mayo that, with regard to the power of transport, the resources of the narrow gauge were such, that nearly 20,000 infantry, with baggage, camp equipage, and ammunition could be placed at Rohree from Lahore in one week; and again, he wrote of the possibility of "throwing 40,000 men in a fortnight on any point of the frontier from Lahore," which he had not the slightest doubt could be done, provided they had the rolling stock. But how was his Lordship's policy about to be carried out by those to whom that duty had been confided? General Strachey and his colleagues on the Committee, Messrs. Dickens and Rendel, said that 30 vehicles of the standard gauge were equal in carrying capacity to 54 of the narrow gauge.

General STRACHEY explained that their estimate was based upon a 2 ft. 9 in. gauge.

Mr. H. LEE SMITH acknowledged the correction; but the carriages for the mètre gauge were only 6 in. wider, and the length was unchanged. Again, that 200 carriages of the standard gauge were required for the transport of 1,000 fully equipped men, with their proportion of artillery, cavalry, cattle, camp equipage, and stores; therefore, taking the same proportion, that 360 narrow-gauge vehicles would be required for this duty; that each train might be made up of 30 carriages, consequently ($\frac{360}{30}$), that 12 trains a day would transport 1,000 men, fully equipped, as before described, from Lahore to Peshawur, which would be equal to 7,000 men in one week. These were the calculations of the Gauge-Committee, but the Author calmly told them that he would take up 11,000 men, not 7,000 men, in a week, and with rolling stock for 2 trains a day instead of for 12 trains a day!

Mr. THORNTON denied that he had said anything of the sort.

Mr. H. LEE SMITH begged to refer to the Paper. It distinctly stated that 11,000 men could easily be moved from Lahore to Peshawur in a week.[1] Mr. Lee Smith would as positively assert,

[1] "Now, although the provision of rolling stock for the future Punjâb lines is intended to be much below that of most existing Indian railways—although, while, according to Mr. Hawkshaw, the average complement of the latter is about

that the sum allowed in the Government estimates for engines and vehicles was no more than sufficient to provide rolling stock for 2 trains a day.[1] He had not lost sight of the arrangement proposed by Government to obviate this little difficulty, namely, that of "concentrating their rolling stock, upon occasion," in some threatened locality. This plan, although it might cause some inconvenience to the ordinary traffic, would no doubt meet the military emergency, which was the main consideration; but there was one element required to insure its successful working, and that was the existence somewhere, in sufficient quantity, of rolling stock to concentrate. There could not be much to come and go upon between Lahore and Mooltan, as that division was to depend entirely for its only concentratable stock upon the sale of a portion of the existing broad-gauge stock, the Author having ruthlessly disallowed every penny put aside by Mr. Fowler for the purchase of a few extra narrow-gauge vehicles. The same arrangement, it might be supposed, as the Author had made no allusion to it at all, was to be effected upon the Scinde line, between Kurrachee and Kotree; but it might be granted that both those divisions were, somehow or other, to be stocked likewise for 2 trains a day. Now, suppose Peshawur to be threatened, and the whole rolling-stock to be withdrawn from the Indus Valley—which, from Lahore to Kurrachee, was three times the length of the Peshawur line—and concentrated at Lahore, this would provide sufficient engines and vehicles for 6 trains in addition to the 2 trains already provided, or in all for 8 trains a day. And rejecting the estimate of Messrs. Strachey, Dickens, and Rendel of 7,000 men per week, carried by 12 trains a day, accept

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one engine, with vehicles in proportion, for every five miles, the Government authorities are of opinion that for the lesser traffic of the Punjâb one engine and thirty vehicles for every thirteen miles may possibly suffice—yet, even with rolling stock at this exceedingly low rate, it has been demonstrated by careful and minutely detailed calculations that, in the course of a week, 12,000 combatants of all arms, infantry, cavalry, and artillery, fully equipped, and with a month's rations, could easily be removed from Lahore to Sukkur, or 11,000 from Lahore to Peshawur, or three corps of 4,000 each, one from Lahore to Peshawur, a second from Lahore to Sukkur, and a third from Kurrachee to Sukkur."—*Vide* ante, p. 227.

[1] Actual allowance of rolling stock, according to preceding extracts:—
"One engine and thirty vehicles for every thirteen miles,"
or, 1 engine to 13 miles.
2·307 vehicles per mile.

Rolling stock required for "two trains each way per diem," *vide* Messrs. Strachey, Dickens, and Rendel's Report on the Gauge question, Parliamentary Return, page 53:—
1 engine to 8·56 miles.
2·336 vehicles per mile.—H.L.S.

the Author's less comfortable allowance of 11,000 men in a week, carried by 8 trains a day — then only, further, supposing the Russians to be smart enough to have been making a feint of coming down the Khyber, the real attack being by the Bolan Pass, or (as they would probably come in considerable strength, if they should think of coming at all) suppose them to appear in great force by both of these passes, our 11,000 troops were being sent up to Peshawur, and there would be the great military line from Lahore to Kurrachee—"of as great strategical importance as any yet to be made in India," 812 miles long, with neither an engine nor carriage to run on it![1] But the more this part of the question was looked into, the more uncomfortable it would be found. The narrow-

[1] What is to be the total quantity of rolling stock between Kurrachee and Peshawur? What quantity of stock would be required for the conveyance of 11,000 men in a week from Lahore to Peshawur? Provision is to be made at the rate of 30 vehicles for every 13 miles, whilst on the two divisions where the standard gauge already exists the Author suggests supplementing the broad-gauge stock "by a quantity of mètre-gauge rolling stock for use on a mixed gauge." Presumably, then, half the stock on these divisions will be broad gauge, and half narrow gauge, or 15 vehicles of each for every 13 miles.

If so, the total mètre-gauge stock, or concentratable stock will be:—

Between Kurrachee and Kotree	105 miles at	15 vehicles per	13 miles	=	120 vehicles.
,, Kotree and Mooltan	493 ,,	30 ,,	,,	=	1,140 ,,
,, Mooltan and Lahore	214 ,,	15 ,,	,,	=	240 ,,
,, Lahore and Peshawur	270 ,,	30 ,,	,,	=	630 ,,
Total number of mètre-gauge vehicles between Kurrachee and Peshawur - - - -					2,130 ,,

Coming now to the second question:—The Gauge-Committee states (page 39 of the Parliamentary Report) that, on the Peshawur line, 12 trains up and 12 trains down per diem, each consisting of 30 standard-gauge vehicles, or 54 narrow-gauge vehicles, would represent the limit of the continuous working power of the line, and would suffice for the conveyance of 1,000 men fully equipped, with their proportion of artillery, cavalry, cattle, camp equipage and stores, per diem, or 7,000 men per week, from Lahore to Peshawur.

Then, in exactly the same proportion, if 7,000 men per week require (24×54) 1,296 vehicles, 11,000 men per week will require 2,036 vehicles, and the effect may be thus:—

Total mètre-gauge stock on the whole line, as shown above -	2,130 vehicles.
Total ditto, which may require to be concentrated north of Lahore	2,036 ,,
Balance then available for the line from Lahore, southwards, to Kurrachee - - - -	94 ,,

94 carriages to 812 miles of line, and no allowance made for any being in the shops or under repair! It must surely be admitted that this is "cutting it rather too fine," and that the provision of stock at the rate proposed, of 1 engine and 30 vehicles for every 13 miles of line, would, in the event of an emergency, prove lamentably insufficient.—H.L.S.

gauge line might, for aught he knew, be equal to the transport of 11,000, or 20,000, or more, troops in a week, if amply supplied with engines and carriages, but certainly not unless it was so provided; and although rolling-stock for 2 trains a day might be more than sufficient for the ordinary traffic, it was absurdly insufficient for a possible military emergency. What was more, he rather thought the Government of India began to have its doubts upon the subject, as he had found, in more than one passage of the Government Reports, a little hint that the rolling-stock might have to be increased to the capacity of 4 trains a day—in plain words, an estimate for doubling it. This, at one fell swoop, would swallow up the whole of the Author's hardly earned saving of £530,000, would leave him, even then, with his line stocked at a lower rate than the neighbouring railways, and with the comfortable reflection that he was cut off from communication with any of the other lines, and had broken the gauge for nothing! He sincerely believed that the Government of India, and perhaps even the Author, began to think it would have been as well to leave the Punjâb lines alone, and, as they could not recall the past, even if that £530,000 of saving were real, which he meant presently to show it was not, to have let it go in completing the 5 ft. 6 in. gauge 'folly' upon which their predecessors had invested, or sunk, £90,000,000 sterling, and contented themselves with a total saving of £9,470,000 instead of £10,000,000.

If there were a grain of sense in this argument he had two suggestions to offer which he would freely place at the disposal of Government. The first was, that if they could afford to spend £7,000,000 in constructing these lines up the Indus Valley to Peshawur but not the additional £530,000 required to make them efficient—taking the Author's figures—the Government had better abandon the idea of a railway altogether, and keep the £7,000,000 in their pocket. After the eloquent description given by the Author of the timely notice we were sure to have of any aggressive movement on the part of Russia, and the perfect deliberation with which troops could be massed at Lahore, ready for projection upon any part of the frontier, he should be disappointed, although that gentleman was not in the habit of adopting his suggestions, if he had not at last placed one at his disposal of which he might be able to approve. But if that would not do, his second suggestion—which he believed would be approved by the entire community of the Punjâb, and by all the military authorities in India, and in England—everywhere, in fact, except perhaps in Russia—was simply to devote the £7,000,000 required for the narrow gauge to the completion of the standard gauge in the Indus Valley, and its extension in the direction of Peshawur for 180 miles above Lahore, up to the great military station of Rawal Pindi, or for 56 miles further, if they pleased, up to the Indus, at Attock, which some people considered was really our proper boundary. By stopping short the railway at even the latter of these two points the cost of a bridge over, or tunnel under, the Indus, and of 44 miles of line would be saved, which together would certainly amount to more than £530,000. Would not this be a better way of saving the money, as the mistake then would not be an irretrievable one? Then, too, they might further economise to any extent in the matter of engines and carriages, putting on just barely sufficient to carry the ordinary, very limited, commercial traffic—2 trains a day—1 train a day—1 train a week if they liked; but relying with confident security, in the event of a military emergency, on the entire rolling-stock of the rest of India. He was certain this suggestion only required looking into to recommend it to the notice and approval both of the Viceroy and of the Commander-in-Chief.

In stating that this great political line, from Kurrachee to Peshawur, would, by the break of gauge at Lahore, be absolutely cut off and isolated from all the other railways of India, he was aware that the Author did not agree with him, because that gentleman had mentioned, as worthy of special notice, that, "the connection of the Indus Valley railways with those of Rajpootana is a project regarded by the Indian Government as one which may deserve to be undertaken at some future period;" and he hinted, but for an excess of generosity on his part, that, were he disposed to be hard on the standard gauge, he might debit that scheme with his £1,000 a mile saving, over the whole length of this connecting link, which, with the line up to the Bolan Pass, he aggregated at "scarcely less than 400 miles."

In this estimate Mr. Lee Smith submitted that the Author was doing his case injustice by his extreme moderation. The length of the Bolan Pass line alone, up to Dadur, was 180 miles, and upon this he had claimed, and credited himself with, his £180,000, leaving therefore only 220 miles to complete the connection between the Indus Valley and the Rajpootana railways. But the actual length of this deserving project of the future was estimated by the Government of India,[1] not at 220, but at "about 410 miles."

[1] *Vide* Supplement to "Gazette of India" of December 30th, 1871, page 1,738, paragraph 14.

Why then had the Author of the Paper claimed no more than £180,000? and only hinted that he might have claimed £400,000? Why had he not asserted his right to (180 + 410 = 590 miles × £1,000) £590,000? Was it pure generosity? or had he some slight misgivings as to the legitimacy of the claim? No one, except the Author, could profess to know, but a very superficial investigation of the facts would lend a strong air of probability to the latter surmise.

The real meaning and object of this line was to supply one solitary channel of communication between the Indus Valley and the Rajpootana narrow-gauge system, which would neither be required, nor, Mr. Lee Smith asserted, would it have been dreamt of, for the next hundred years, if the standard gauge had been maintained between Kurrachee and Peshawur. The line in question would not in any way promote one of the greatest, if not the chief, object of the through lines, in—to quote the words of the Secretary of State's despatch — "abridging the distance from Bombay to Lahore," or, in "giving a new approach to Lahore from the sea." On the contrary, it would lengthen the journey between Bombay and Lahore, either of private individuals, who might have time enough on their hands to prefer that route, or of troops, by just 310 miles.

However, as they had heard, on such high authority, that the line was actually spoken of as one which might hereafter be undertaken, such a probability could not be ignored, and he would therefore earnestly beg the attention of the meeting to the financial aspect and probable commercial results, of such a project. Lord Lawrence wrote that "a line might be contemplated from Kotree, *viâ* Luckput, through Cutch, to Ahmedabad," but the Government of India would appear to have rejected that suggestion, as he found it stated in a later despatch of October, 1871, that "this connecting link might be made from Ajmere, *viâ* Jodhpoor and Jeysulmere, to Rohree, length about 410 miles," and he had not the slightest doubt that it might. Indeed, after rejecting the route proposed by Lord Lawrence, the choice left with the Government of India was a very wide one, and about as eligible as that supposed to lie between the frying-pan and the fire. He admitted that he had never been in Kattywar or Cutch, and that he did not speak from personal observation, but he had read up the best authorities he could find on the subject, and had noted the following interesting particulars of the country this line would have to traverse, or through which it would have to thread its way.

Commencing from the south, the "Great Runn of Cutch" was described as "a vast salt morass, flooded in the monsoon by sea-water blown into it," the only other features which he had noted, but which were of little importance from a traffic manager's point of view, being that it is much frequented by wild asses, whilst in the dry season it swarms with flies.

Scinde was described as "shut in between a vast desert on the east and a lofty mountain range on the west." In the southern portion of it was the "Little Desert," a proud distinction, preventing, it might be hoped, the danger of its being confounded with its immediate neighbour on the north, which rejoices in the name of the "Great Desert."

Of Ajmere, still further north, it was said, "the general appearance is sufficiently dismal, a considerable portion of it being absolute desert, whilst the last 100 miles south-west of Bahawulpoor is wholly destitute of water, vegetation, and inhabitants," and Jeysulmere, upon which the mantle of choice seemed to have fallen, was said to be "surrounded by a great desert, of which it may almost be described as an integral portion." Such were the descriptions given of the inviting regions into which the Government of India felt itself bound to contemplate the construction of a railway; bound, moreover, solely by the proposed break of gauge upon the Indus Valley system. For, were it not a matter of sheer necessity to provide some channel for the interchange of carriages or the supply of reserve stock from Central India, he confidently submitted that a railway 410 miles long, through such fearful districts, would stand as much chance, and no more, of being taken up, as a line through the centre of the Great Desert of Sahara.

After the picture drawn, too, of the injustice, or the hardship, at least, of forcing railway blessings upon people at a price beyond their market value, he would be surprised if the Indian tax-payers did not keep a watchful eye upon any steps which might be threatened for the commencement of this truly dismal project; and meanwhile, he would only submit that, instead of pretending to claim £410,000, or even £220,000, as a saving, which would result from making this a mètre, instead of a standard, gauge, the saddle should be put on the right horse, and the whole cost of its construction (at say £5,000 a mile × 410 miles = £2,050,000) should unquestionably be debited to the former, the shortcomings and weaknesses whereof formed the only grounds upon which such a line could ever be deemed necessary, or could stand a chance of being undertaken.

All this while, he had been proceeding on the assumption that the Author had, by some of these more than doubtful expedients, established a claim to a saving of £530,000, which, however, Mr. Lee Smith now confidently repudiated. General Strachey's figures were not, as he thought he had already shown, in a sufficiently mature state to be attacked. That officer might easily, had he been so minded, have given them quantities, weights, and prices, and allowed them a fair opportunity of examining them; but if he had done so it could easily have been shown that his estimates were unsupported by reasoning or facts. Mr. Lee Smith had also, he believed, proved that the original attempt on the part of the committee to establish any appreciable economy by reducing the gauge in the Indus Valley had broken down. Under these circumstances, and always supposing that Government condescended to argue the question, and not merely to stand upon its right to do what it pleased about the gauge, without reference to anybody's figures or opinions, it was perfectly evident that a new case had to be made out, a task which the Author accordingly proceeded to execute in a vigorous and independent manner. He threw over the Secretary of State's orders as regarded laying a third rail on the Scinde line, and decided to reduce it to a mètre gauge, whilst the opinions of the Government of India as to reserve rolling-stock for military emergencies were treated with sublime indifference.

To the first of these proposals, namely, to reduce the gauge of the line between Kurrachee and Kotree, probably the Scinde Railway Company might have something to say; but how about the second proposal, to dispense entirely with the extra rolling-stock required by the dislocation of the gauge?—the necessity for which had been recognized, as far as he could learn, by every person who had ever been asked for or had given an opinion on the subject, excepting by the Author.

He found, for example, from official documents, that the Viceroy in Council—who was generally allowed to have a voice in the matter,—had "no hesitation in adopting the conclusion that this Peshawur railway should be designed and carried out, so as to ensure the smallest expenditure that will provide a thoroughly permanent and useful iron road, that can be traversed by the ordinary locomotive and wagon stock in use on the Punjâb and East Indian railways at a low speed."

If this were not sufficient he could quote the opinion of the Secretary of State, who first gave his assent to the construction of this railway, namely, "that a second class line, such as has been proposed by Colonel Strachey and others, would fail to secure any very important advantage," and could give five other extracts from the Government despatches, all fully recognizing the importance of being able to draw upon the other great Indian lines for reserves of stock; which, however, the Author not only disdained, but declined to allow one penny for extra narrow-gauge stock, which would, to some extent, have made up for the loss of use of the broad-gauge stock.

It was certainly a bold theory to advance that, "for the Lahore-Peshawur section, the cost of providing rolling stock sufficient for ordinary traffic would be the same whether the gauge were broad or narrow," for that was simply to say that a narrow-gauge railway, isolated from all the other lines of India, stocked at the miserable rate of 1 engine and 30 vehicles for every 13 miles, would no more require any extra stock, and would therefore, in other words, be as reliable and efficient as a standard-gauge railway would be when in free communication with some 5000 miles or 6000 miles of fully stocked line at its back; but he could not express his opinion of such sophistry without departing from his good intention to speak with becoming respect of a favourite Government project. Had he known the ground the Author intended taking up Mr. Lee Smith could have offered him rather a good suggestion, namely, that he should adopt the more decided opinions upon a break of gauge, recently laid down in a publication entitled, "The Battle of the Gauges," and reproduced in the "Times," of the 17th February, 1873, in an extremely flattering review of that work. The following were the exact words:—"When a long journey has to be continued over the lines of different companies, a break of gauge where these lines join would be a positive saving." Now that was something like an argument! and if it were sound Mr. Lee Smith was doing a service in calling prominent attention to it. What a chance for Government when they took over the Irish railways! And as no opportunity of effecting a 'positive saving' should be neglected, a few judicious breaks would probably be introduced into the English railway system as well. But meanwhile, until this theory was more fully developed and explained, he suspected the Meeting would not be driven from its old-fashioned idea that a break of gauge was a source of delay, loss, and grave inconvenience. As for the Peshawur line, the rough common-sense idea would be, that instead of narrowing the gauge at Lahore the funnel ought there to be widened, or that the desired saving might be better effected by retaining the standard gauge and economising in the item of stock.

But all these suggestions were overruled; a sum of £6,000,000 or £7,000,000 was to be expended on the construction of a line declared to be "of the highest political importance," and "of as great strategical importance as any yet to be made," and which, to be kept down to that figure, to save £530,000, was to be stocked on literally the starvation principle, contrary to the wishes of even its own promoters! He thought the Meeting would unanimously agree with him that the game would not pay for the candle, and that to expend £6,000,000 or £7,000,000 upon a half useless undertaking would be a criminal waste of money.

A very curious argument was advanced against borrowing rolling-stock if the standard gauge had been preserved. It was stated in the Paper that:—"Heavy-line engines could not be permitted to travel upon their light rails; so that, in order to be able to utilize on emergency the borrowed vehicles, it would be necessary always to maintain on the Punjâb lines a duly-proportioned number of reserve engines to haul them, the enormous expense of which would of itself be an insuperable objection to borrowing."[1] This was clearly an admission that the traffic superintendent on an emergency might find himself short not only of wagons and carriages, but of engines as well! Admitting the possibility that he might require to borrow five shillings, he allowed an insurmountable barrier to be placed between himself and his friendly neighbour, who said:—"If ever you should find yourself in such a fix, you may rely on me for half-a-crown." But why did the Author build all this part of his argument on the supposition that the standard gauge must of necessity be a light line, and shut his eyes so resolutely to the possibility of using a heavier rail? A very fair start in this direction had actually been made, as rails intended for the Peshawur line, weighing 60 lbs. to the yard and sufficient to lay 100 miles, had already been sent out. What the Government of India proposed to do with these rails he did not know. They had told the Secretary of State that "they can be used elsewhere, probably on the Rajpootana line," but as that was also to be a light mètre-gauge line the advantages of the suggestion were not very apparent. Disregarding, however, such experience as Mr. Harrison's of what he had done with 40-lbs. rails, when he had run the traffic between England and Scotland over them for about four years—had the Author reckoned the additional cost of making these Punjâb lines fit to carry, not only the vehicles, but also the engines, of the

[1] *Vide* ante, p. 226.

neighbouring lines? This could probably be done most cheaply in the first instance by increasing the number of sleepers and putting them closer together, but a better plan would be to increase the weight of the rails up to 50 lbs. per yard. He had estimated what it would cost to do that upon the Indus Valley line, carefully worked out at the prices quoted in the officiating Chief Engineer's estimate, dated only a few months back, and allowing for the extra quantity of ballast and for the additional length of sleepers, he found it would be just £250,690. And upon the Peshawur line about—for in this case he had not the Government rates[1]—£133,650. These were not large sums to pay for insuring beyond the possibility of doubt the efficiency of two lines, upon which, almost entirely for strategic reasons, it was deemed necessary to spend £7,000,000.

One word more about the rolling-stock. The Author disallowed the amount claimed by Mr. Fowler and everybody else, for working through traffic on the narrow gauge between Mooltan and Lahore, on the ground that the balance of broad-gauge stock on that division, which other lines had not been polite enough to buy, would remain to supplement the narrow-gauge stock which he proposed to put on. Now what did this disallowance involve? Something very like a second break of gauge at Mooltan! The traffic, it was to be observed, was to come up by a single narrow-gauge line to Mooltan, but at that point it was to be split up and put into the stock of two different gauges!

Why, in addition to all the other perfect arrangements for the harmonious working of their state lines, Government would have to rear or design a special race of porters and station-masters, as no ordinary man could possibly be expected to solve the problem presented to him on the arrival of each train—that of filling the broad-gauge trucks with $1\frac{5}{9}$ths of the load of two of the narrow-gauge ones, and *vice versâ!*

The thing, of course, was a farce; it could not possibly work for a month; the third rail would be of no more practical use than a third leg to a pair of breeches; and the result would be that one of the present rails of the Punjâb line would speedily be thrown out of gear, leaving the bulk of the traffic for conveyance on the mètre-gauge line, with the latest mechanical novelty, a 68-lbs. rail on one side, and a 40-lbs. rail on the other.

[1] Mr. Lee Smith, however, had taken the price of iron delivered on the line at £20 10*s.* per ton, instead of £16 10*s.* as quoted in the estimates of Messrs. Fowler, Strachey, Dickens, and Rendel, and the sleepers at the price at which Messrs. Brassey, Wythes, and Henfrey, had been buying them.—H. L. S.

To come now to the Indus Valley line, which was declared by the Government to be "of as great strategical importance as any yet to be made," he maintained that it was being made on the wrong side of the river, and he had much more weighty testimony on this point to produce. Lord Lawrence said it should be "on the other side of the Indus to that occupied by the main line from Kurrachee to Kotree;" whilst Lord Napier of Magdala, whose opinion, as Commander-in-Chief, upon a strategical line was surely of the greatest importance, had recorded in a separate special minute, that he dissented from the proposed adoption of the right-bank side. He had seen in a recent official despatch that the length of this right-bank line was greater by 34 miles than that on the left-bank, whilst the Government of India admitted that, owing to uncertainty as to the cost of the bridges, the total cost of either line might be considered the same. Setting aside, therefore, the disadvantage of increasing the length of journey by 34 miles from the seaboard—had the Government of India calculated the cost of working and maintaining that extra 34 miles of line? He found that, taking 2 trains each way daily, which was the basis of the government calculation for rolling-stock, the cost of working and maintaining these 34 miles of line—capitalised—would come to £223,360, or £103,360 more than the estimate of the Government officers for a second bridge over the Indus between Rohree and Sukkur; so that by adopting the left-bank line, with a second bridge at Sukkur, the Government of India would save 34 miles of permanent detour, £103,000 in cash, and would have their line on the safe side of the Indus, as demanded by the Commander-in-Chief. He would now beg to direct the attention of the Meeting to the relative cost of constructing the Indus Valley railway on a standard, or 5 ft. 6 in. gauge, and, on a mètre, or 3 ft. $3\frac{3}{8}$ in. gauge; and in doing so, as the Author had quoted chiefly from Mr. Fowler, so Mr. Lee Smith proposed to do the same, in every case where Mr. Fowler's figures were available. He would have given his own figures, which were worked out in greater detail, and would, he believed, be much nearer the truth, but he preferred quoting from those high authorities whose opinions ought to command more weight.

In explanation of the table which he had prepared, of the "Estimated cost of constructing the Indus Valley railway" (page 307), he stated that he was well aware that Mr. Fowler's price for rails was much under the present market-rate, but so also, as it happened, was the price quoted on the mètre gauge side of the account, and the comparison, therefore, was perfectly fair.

ESTIMATED COST OF CONSTRUCTING THE INDUS VALLEY RAILWAY.

With a standard, or 5 ft. 6 in. gauge.		With a mètre, or 3 ft. $3\frac{3}{8}$ in. gauge.		
	£			£
Mr. Fowler's estimate	3,056,404	Mr. Molesworth's Report, Consulting Engineer to the Government of India . . .	271 miles × £6,300 =	1,707,300
Addition on account of 13 miles extra length of line, at the same rate	85,394	Ditto ditto . . .	222 miles × £6,000 =	1,332,000
Extra cost of the line up to the Bolan Pass if made on the standard gauge, claimed by Mr. Thornton	180,000	Consulting Engineer to Bombay Government, estimate of Indus Bridge at Sukkur		120,000
		Additions:—		
		Messrs. Fowler and Thornton's estimate of altering the Scinde and Punjâb railways . .	£327,177	
		Additional cost of altering the Scinde line, which is 165 miles long with its sidings, instead of 105 miles as estimated by Mr. Fowler . .	£22,500	
		Messrs. Strachey, Dickens, and Rendel's estimate for altering Lahore station	£17,500	
Total of standard gauge . .	3,321,798	Transport, sale, and loss upon rolling-stock of Scinde railway, say	£19,000	
Balance in favour of ditto . .	223,679			386,177
	£3,545,477	Total of mètre gauge . .		£3,545,477

The estimate of Mr. Fowler for a line upon the standard gauge, between Kotree and Mooltan, was £3,056,404. To this he should make an addition of £85,394, the second item, on account of 13 miles extra length of line, Mr. Fowler having taken the line as 480 miles instead of 493 miles in length; and the third item was the £180,000 claimed by the Author as a saving to be effected by constructing the line between Sukkur and the Bolan Pass upon the mètre gauge, and which—although, upon such a piece of line, it seemed quite three times as much as ought fairly to be claimed—Mr. Lee Smith meant to allow rather than dispute. These three items would give the total cost of the standard gauge as £3,321,798.

He would now explain the items in reference to the mètre gauge on the other side of the diagram, namely:—

Miles.		£
271 × 6,300	=	1,707,300
222 × 6,000	=	1,332,000
Indus bridge at Sukkur		120,000

The Meeting would probably desire to know whence he got those figures. They were taken from the report by the Consulting-Engineer for State Railways to the Government of India, who stated [page 10, par. 17] that the cost of the line would be as he had quoted; namely, between Mooltan and Kotree, about £6,300 per mile; and between Rohree and Kotree about £6,000 per mile. The estimate of the Indus bridge at Sukkur, was that made by the Consulting-Engineer to the Bombay Government; and although he considered it greatly under the mark, he preferred to take those figures.

To these three items certain additions were required to be made. The first, of £327,177, was Mr. Fowler's estimate of the alterations upon the Scinde and Punjâb railways, and which sum was admitted by the Author. The second item, of £22,500, was on account of an error made in the length of the sidings of the Scinde railway, which, with its sidings, was 165 miles, instead of 105 miles in length, as quoted by Mr. Fowler, and which would, therefore, require alteration to the further extent of the item quoted. The third item was for the alteration of the main changing-station at Lahore, which Mr. Bidder had put down at £50,000. Mr. Lee Smith had taken it at the more modest figure of £17,500, which was the sum allowed on this account by Messrs. Dickens, Strachey, and Rendel; and the last item was on account of the carriage and sale of the Scinde railway stock, the depreciation of which, in Mr. Harrison's opinion, should be taken at 50 per cent.; but which he, to be on the safe side, had taken at the moderate figure of 10 per cent. These together amounted to £386,177, which had to be added, to arrive at the total of the mètre gauge, and which left a grand result in favour of the standard gauge of £223,679.

He had quoted the principal figures upon this side of the account from the report of the Consulting-Engineer to Government as being the highest authority on the subject, though he did not suppose that the estimates of £6,300 a mile, or £6,000 a mile, professed to be perfectly exact. It was in the power of the authorities of the India Office to invalidate his calculations by informing them that they had received later and more precise information; but if challenged upon this point, he would at once produce incontrovertible proof that the figures were quite accurate enough for his purpose, which was, to show that the economy put forth as the plea for breaking the gauge of the Indus Valley line had no foundation in fact; that, on the contrary, there was a decided balance in favour of the standard gauge; and he hoped the Meeting would now appreciate, and possibly would even join in, the Commander-in-Chief's protest, recorded thus in his Lordship's own words:—"I dissent from the 24th and 27th paragraphs. I am unable to consider the construction of the Indus Valley line on a broad gauge 'a financial impossibility' under the present circumstances of India."

Here they ought to stop. There was no need to say a word about the Peshawur line in the face of the admission made by the Governor-General and his council in these words:—"We have no hesitation in saying that were it a question of the section between Lahore and Peshawur alone, we should at once dismiss from consideration all idea of anything but a standard-gauge line." It was futile to argue, that because the Government had now elected to follow the line of the Grand Trunk road there was the slightest necessity for doing so. The original order for the examination of that line ran thus:—"Between the two termini, Lahore and Peshawur, there is but one intermediate compulsory point through which the line must pass, and that is Rawal Pindi."

Bearing this in view, Mr. Lee Smith decided to take the shortest route admissible by the natural obstacles of the country, which would secure the carriage of the salt, the only existing important traffic of the district. In doing so, he had the high approval of Lord Lawrence, who advised that the line should go by the salt mines.[1] In short, the line which he recommended was approved

[1] "I incline to think, with Colonel Strachey, that the most convenient line for a railway would be from Lahore to Goojerat and thence by a curve to Pind Dadun Khan."—*Minute by the Right Hon. the Governor-General, dated 27th March, 1865.*

by the Punjâb Government and by all the authorities, but the whole project was abandoned for the time on account of the expense. How the Grand Trunk road line came afterwards, and through a complete mistake, to be adopted was a long story. He told Lord Mayo that the utmost he would save by cutting up his second line of communication, the Trunk Road, would be £200 per mile, and his Lordship said, half laughingly, "And a very important saving too!"

But to conclude. The new orders for the State railways, with curves of 330 ft. radius, and gradients of 1 in 40, instead of 1 in 70, as he had previously been working on, at once removed all objections on the score of heavy works, and made the line *viâ* the salt mines feasible, and on seeing this, he wrote without delay, as a Government servant, and begged that the matter might be reconsidered. This was on the 16th of February, 1871, exactly two years ago. He stated that the line "would be straight, almost as the crow flies, and could be made as cheaply as the Great Trunk road one." He tried all his powers of persuasion, and even after he left the service, he still continued to urge the advantages of the salt line upon the notice of the authorities. He worried every one whose influence he thought might be brought to bear on the subject to listen to him. But all was of no avail. He begged one of the members of the Finance Committee to have him summoned, who promised, that if the other members thought it worth while, he would endeavour to do so; but Mr. Lee Smith had heard nothing further on the subject.

He had made similar calculations with respect to constructing the Peshawur railway on the standard gauge, and the results were shown in the table (p. 311). He found that by following the direct line there would be a balance in favour of that gauge of £253,828. Believing that where the gauge of these two lines—"of as great strategical importance as any yet to be made in India"—was hovering in the balance, the subject was worthy of the serious attention of Government, he used his best powers of persuasion, not in writing only, but in a personal interview with the Under-Secretary of State, to induce him to refer the matter to a committee, alleging that half an hour would suffice to test the truth or the fallacy of his assertions, but without avail. In conclusion, he begged leave to record his firm conviction that the break of gauge would certainly result in a clear loss of not less than £300,000 or £400,000.

Mr. J. Allport said that, as his experience in the working of railways had extended over a great many years, and for a consi-

ESTIMATED COST OF CONSTRUCTING THE PESHAWUR RAILWAY.

With a standard, or 5 ft. 6 in. gauge.	£.	With a mètre, or 3 ft. $3\frac{3}{8}$ in. gauge.		£.
Offer made by influential contractors to make the whole line (and salt branch) from Lahore to Peshawur	3,464,400	Mr. Molesworth's Report, Consulting Engineer to the Government of India . . . 340 miles × £6,400 =		2,176,000
Government supervision at, say, $2\frac{1}{2}$ per cent. . .	86,610	Ditto ditto for the three great bridges .		1,125,000
Add for rise in price of iron since the offer was made	76,380	Ditto ditto for a second bridge across the Jhelum, taken at the same rate		250,000
		Additions :—		
		Loss upon 100 miles of heavy permanent way sent out for this line, being the difference between 60-lbs. rails and 40-lbs. rails and fittings . .	£63,558	
		Loss on carriage of salt over 30 miles of line needlessly. Estimated out-turn = 100,000 tons, at 1*d.* per ton per mile, = £12,500 per annum. Transfer from narrow-gauge trucks to broad-gauge trucks at Lahore of, say, 50,000 tons, at 4*d.* = £833 6*s.* 8*d.* per annum; together, £13,333 6*s.* 8*d.* capitalized = . . .	£266,660	
Total of standard gauge . .	3,627,390			
Balance in favour of ditto . .	253,828			330,218
	£3,881,218	Total of mètre gauge . .		£3,881,218

derable portion of the time in connection with 'break of gauge,' he might venture, without alluding especially to Indian railways, to state what his views were upon that point, and also in reference to the relative advantages of the broad gauge and of the narrow gauge in Great Britain.

With regard to break of gauge, his experience had been considerable for some years past, inasmuch as a portion of the Midland railway had been constructed on the broad gauge and another portion on the narrow gauge. The break took place at Gloucester, and such were the evils it entailed, that many years ago the company determined, at great cost, to make eight miles of narrow-gauge line, and to convert the old line into a mixed gauge. The Act authorising the conversion provided, however, that the broad gauge should not be taken up; and though that broad gauge, by Act of Parliament, was obliged to be kept down, because it was in connection with the broad gauge from Bristol and also from Gloucester, yet from the time the narrow gauge was opened, not a single engine passed over that broad gauge to and from Gloucester, and the greater part of the rails had been kept down almost to the present day —certainly till within the last twelve months. Now the transfer of the traffic at Gloucester was so great an evil, that the South Wales railway and the Midland railway absolutely made arrangements for allowing eight miles of mileage to compensate for that break of gauge; whilst in another case, the allowance was now twenty miles. He had frequently had occasion to mention it before committees of Parliament; he thought in all cases the delay of the break of gauge was never less than one day, and very frequently it was two days.

The question of salt had been alluded to, and up to the present day a large amount of salt was transhipped from the narrow gauge to the broad gauge at Bristol, and that was done, not only at considerable expense, but at great loss.

In reply to Mr. Thornton's question—through the President—of what quantity of salt was brought? Mr. Allport said, that not intending to take part in the discussion, he had not brought any figures with him; but there were many thousand tons a year, but whether it was 10,000 or 100,000 the question was the same. There could be no question that upon low-priced articles like salt and coal, the break of gauge was destructive to the traffic; and he ventured to ask practical men whether it was possible, looking at the mineral traffic carried on many British lines—taking the Midland railway as an example, carrying between eight and nine millions of tons of coal alone—with all the appliances that could be arranged, to tranship that quantity of traffic; large or small, the question of cost per ton must be the same, providing there was sufficient traffic to occupy a certain number of men, wagons, and trucks. And it must be a poor traffic indeed that would make the cost, because of its smallness, larger per ton than if they had a large traffic to deal with.

With regard to the goods traffic generally, a narrow-gauge truck would take from 5 tons to 6 tons, and a broad-gauge truck would carry 10 tons. Supposing there were not 10 tons to put into a broad-gauge truck, the same quantity had to be taken in a broad-gauge truck that could have been loaded into a narrow-gauge truck, and that, he need not remark, was a great loss; such was the practical experience of men who had had this transhipment under their observation. The result was, they transferred from the narrow gauge to the broad gauge the same goods, and the extra weight of the broad-gauge trucks must be so much loss as dead weight.

A few years ago experiments were made at the instance of the War Office, in loading a battery of six guns, with horses and equipments, partly at the King's Cross station and partly at the Euston station, to travel a certain distance and then to unload. Any one who witnessed that operation must be convinced that to tranship an army of even only 20,000 men or 30,000 men, with horses and equipments, would be so prejudicial and would cause such a vast loss of time, that it would be better, in his judgment, for the army to march by the road rather than to undergo that transhipment. He did not believe it could be done. The difficulty of getting horses out of one truck and putting them into another was so great, that he did not think any officer would undertake the task; and as to the guns, the difficulty of getting them first into the trucks and then shifted to a different gauge would be so great, that the time lost and the expense of it would justify a commanding officer in deciding to take his guns by road rather than by railway. He knew from experience the difficulty of getting a large number of horses into trucks of the 4 ft. 8½ in. gauge; how they were to be carried on the mètre gauge he was at a loss to understand; and he thought that remark would apply to a very large amount of what was termed the 'impedimenta' of an army. Then, again, with regard to the men—they could not be expected to carry all their accoutrements with them in the carriages. In the conveyance of troops the muskets were generally put into separate vans, and it was an easy thing if they had 50 trucks of one gauge to put their contents into 50 other trucks of the same size and gauge, much easier than to put the loads of 50 broad-gauge trucks into 70 narrow-gauge trucks or 80 narrow-gauge trucks. The difficulty of the men finding what belonged to them would increase the difficulty of moving an army under such circumstances. This last autumn he was requested, being in Canada, to give his opinion with respect to the Grand Trunk railway in that country. One of the first difficulties that struck him was the break of gauge on that railway. After discussing the question with the President of the company, the Engineer, and the Manager, it was decided unanimously to recommend the shareholders to expend a very large sum of money in altering the gauge of that line. He regretted that the poverty of the company compelled them to limit the change of gauge to a certain portion of the line only, as he was convinced it would have been a great benefit to them if they had altered their entire system to the ordinary gauge of that country. He regretted he had no facts and figures with him to bear out what had been said by the last speaker and by Captain Galton. He thought if there was a curse on a railway system in any country it was having different gauges. It was the duty of the government of any country to insist upon a uniform gauge. The adoption of the narrow-gauge for the lines proposed in India might entail the loss of that country to the governing classes; and he would strongly urge upon all who had any influence in deciding this question to insist upon the entire railway system of India being constructed upon one uniform gauge. He did not wish to say the mètre gauge was superior or inferior to the 4 ft. 8½ in. gauge, the 5 ft. gauge, or the 5 ft. 6 in. gauge. He had, however, a strong opinion in favour of the 4 ft. 8½ in. gauge, or, at the most, the 5 ft. gauge; but what he did say was, that in his judgment, for the welfare of the country it was imperative upon the Government to insist upon one uniform gauge.

Captain Tyler, reading from copious notes, said he had felt great hesitation in taking part in this discussion, but it had been represented to him that as he was the first to bring the subject of railways on a narrower gauge than 4 ft. 8½ in. before the Institution,[1] and as he had since taken a somewhat prominent part in experiments and discussions on the subject, it would, or might, be supposed, if he did not now express a contrary opinion, that he was in favour of an universal mètre gauge for the Indian State railways. He could fully appreciate the position of the Indian Government in this matter. They

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xxiv., p. 359.

had constructed and guaranteed interest on the cost of 5,000 miles of railway, in a country 1,800 miles long by 1,500 miles wide, containing 200,000,000 of inhabitants; they conceived rightly, that, for the due development of the country, it was essential to construct a further network of, say, 10,000 miles of railway: and they believed, rightly also, that it was of great importance to effect as much saving as was consistent with efficiency on this large system. They were naturally disposed to look despondingly at the heavy interest which they are called upon to pay for existing lines, and were as naturally desirous of making future lines pay interest on the outlay to be incurred on them. They, therefore, took up warmly the question of narrow-gauge construction, and they were desirous of utilizing it to the uttermost.

Now, as a warm advocate of a narrow gauge in its proper place, he had been quite unable—and he was glad of the opportunity of saying so publicly—to follow the later advocates of narrow gauge into all their extremes, and he also dissented from those uncompromising opponents of narrow-gauge lines who would oppose them in all cases and under all circumstances. There were gentlemen who would tell them that the heaviest traffic might be carried more cheaply on a 3 ft. gauge than on a 4 ft. 8½ in. gauge, or a 5 ft. 6 in. gauge, on the one hand; and there were others who would tell them that the narrow gauge was not capable of being worked with sharper curves, and was hardly less expensive in a difficult country, on the other hand. He did not care to discuss the matter with gentlemen holding either of these opinions. But he did believe that a 3 ft. gauge or a 3 ft. 6 in. gauge was suited to some circumstances, and that a 4 ft. 8½ in. gauge or a 5 ft. 6 in. gauge was suited to some other circumstances; and the question at issue was, to what circumstances were they respectively suited?

The elements to be considered were:—

1. First cost in construction,—comparatively.
2. Cost and efficiency of working and maintenance,—comparatively.
3. Nature and quantity of traffic.
4. Gauge of existing railways, and number and position of points at which there would be break of gauge.
5. Strategic requirements.

These points required to be considered separately and carefully, with reference to each particular line to be constructed; and they led to other important considerations, such as speed and general efficiency.

In the present instance, the Author, taking the best materials in his possession, endeavoured to arrive at a comparison of cost which was evidently anything but reliable, when applied to 10,000 miles of railway over a country of vast extent, presenting great varieties of character, climate, and traffic; and he rather summarily disposed of the question when he said that there must be either narrow-gauge railways or no railways at all. Perhaps the Author would be nearer the truth if he were to say that India must have railways, of whatever gauge; but they ought to be made in the cheapest possible way, consistently with the most economical and efficient working and maintenance.

Various opinions had been expressed as to the saving to be effected by the adoption of the mètre, or narrow gauge. This was estimated by Mr. Bruce at £200 per mile, by Mr. Harrison at £400 per mile, by Mr. Thornton at £1,000 per mile; by Mr. Fowler and by Mr. Hawkshaw at different figures between these extremes; by General Strachey at £1,000 per mile to £1,500 per mile, in permanent way alone, and as much more in other items, say £2,000 per mile. Now the extreme difference between £200 per mile and £2,000 per mile, multiplied by 10,000 miles, became no less than £2,000,000 against £20,000,000.

The Institution ought not, and it could not, seriously discuss the question without more accurate information of a reliable character. Mr. Harrison did the best he could, with the information before him, to pull to pieces the estimates of two other eminent Engineers of the greatest experience, and to found his own conclusions upon the ruin which he had effected; but Captain Tyler hardly supposed that Mr. Harrison's conclusions would be quite satisfactory to himself, and he was sure that Mr. Harrison would prefer, and would be the first to advocate, that in a comparison of cost as between two gauges, the precise line of railway should be indicated, precise information in regard to it should be obtained, and accurate estimates of that particular line should be framed.

Captain Tyler held that the method adopted by Mr. Thornton, of averages between Mr. Fowler's estimate and Mr. Hawkshaw's estimate, produced results which, under different circumstances, and for different lines, were entirely fallacious. Facts and figures were proverbially deceptive, but averages were perhaps still more deceptive. He remembered in one case finding fault with some fish-bolts which were too short, and having it pointed out to him that, as others were too long, the average was sufficient. Similarly, when, on a very recent occasion, he had referred to a train as having been run on certain days at too high a speed, he was met by the reply that the average running speed of the same train for the month had not been excessive. The absurdity of such averages was obvious, and it was, he contended, almost as improper to take any average between the estimates of £200 per mile and £2,000 per mile above referred to—and to multiply it by 10,000, in order to arrive at the saving of the mètre gauge over the 5 ft. 6 in. gauge, for future Indian railways. Some of the projected lines would show a greater, others a less saving in this respect; and it was only right and proper to take each case, with accurate estimates and information, on its own merits, and then duly to weigh the different conditions of the problem.

Another instance of the fallacy of averages improperly applied had been afforded by General Strachey, who had cited the average traffic carried on a working railway, and then contended that—as such average traffic could be carried on a railway on the mètre gauge — railways on the mètre gauge would be capable of doing all that could be required of them. The traffic on the East Indian railway was, he apprehended, much greater on some parts than on other parts of the line, and at certain times and seasons, than at other times; and the same would be the case on the lines yet to be constructed. And any one, who knew anything of railway working, was well aware that the inconvenience of a crowded traffic, which was severely felt at certain times and seasons, and on certain lines, would be very easily dealt with, if it could be averaged and distributed at the pleasure of the traffic managers. To take a familiar instance, the carriages and platforms of the Metropolitan railway were sometimes overcrowded and sometimes empty; or take the case of Easter traffic or Christmas traffic in this country, or the Scotch traffic at certain seasons, and the same was the case. The question really was, whether the mètre gauge would be sufficient for the maximum traffic that could be brought upon the lines constructed on that gauge, at all times and all seasons, rather than whether it was adapted to the average traffic of any existing line. What that traffic was, over all or any of the various lines proposed, they had no present means of knowing, and it was therefore impossible for them profitably to discuss further this part of the subject.

Then, again, the comparative cost and efficiency of working and of maintenance, as between the two gauges, depended upon the character and quantity of the traffic; and there was one point that he had not heard referred to in the course of this discussion—that of speed. It was obvious that, on long lengths of line, it might be a great object to run, at times, if not with daily trains, at a high rate of speed, in order to save time on long journeys; and the mètre gauge could not be considered to be well adapted for such high rates of speed. On lines, therefore, on which high rates of speed might be required, it was one argument against the mètre gauge that it was not so well adapted to high speed as the 5 ft. 6 in. gauge, and especially if stability were to some extent sacrificed in the rolling-stock.

The disadvantages, which he had seen in practice for so many years, of the break of gauge—which had at length been happily put an end to in South Wales—had been already sufficiently referred to; and Mr. Allport had referred to the change of gauge that had been lately effected on a line with which Captain Tyler had been many years connected in Canada. The circumstances of the Grand Trunk railway were peculiar. A break of gauge had there actually been effected during the past year between one part of the line and another; and that which was ironically proposed by a previous speaker had thus been carried out in practice. The gauge of that railway had been narrowed for 180 miles between Sarnia and Fort Erie, on the opposite side of the Niagara river, to Buffalo, from 5 ft. 6 in. to 4 ft. 8½ in.; and the lesser evil of a break of gauge had been incurred—it was hoped temporarily—at Stratford, in order to avoid the greater evil of the break of gauge at two important points on the line, which were in connection with the great American lines of railway. The Author, however, spoke of a break of gauge as not being of great importance, for he said :—"If, in some unforeseen emergency, a regiment ever did arrive by rail at Lahore, requiring to be sent forward immediately, the only time lost would be the half hour or so spent by the men in walking from the broad-gauge train to a narrow-gauge train, already laden, in anticipation of their arrival, with whatever guns, ammunition, &c., were needed for their full equipment. This occasional half hour or so would be the only delay (if any) which ever could be caused by break of gauge." [1]

All those who had studied the question of transporting bodies of troops by railway would well understand what he meant when he said that the difficulty was not to run trains along the lines, but to collect the necessary rolling-stock at one end, to arrange for the arrival of the troops, horses, guns, munitions, provisions, stores, &c., to get the soldiers into the carriages, to embark the 'matériel,' &c., to send them off train after train, and then to disembark them at

[1] *Vide* ante, p. 226.

the other end; and they would further understand the difficulties, delays, and confusion which had to be encountered, in remembering that a break of gauge necessitated all those operations being gone through twice over. In this case of the Indus Valley line, there were 1,000 miles between Kurrachee and Peshawur, and he need not dwell upon the importance of being able, in a case of emergency, to transport troops rapidly over portions or the whole of that route. They had been led to believe that one great advantage of having railways in India would be, that they might without fatigue to the troops by long marches, take them through the country, and whilst employing smaller forces, be prepared to concentrate within a short period the number of men required at any point. He maintained that, not only by break of gauge in certain localities, but also by using the mètre gauge for certain through routes and in certain localities, they would do away with many of the advantages which had thus been anticipated from having railways in India.

In conclusion, he said, the question before them was a very serious one—serious to the Indian Government—serious to the maintenance of the British rule in India. It was one which ought only to be decided after the most careful computation, the most careful inquiry, the most detailed examination. It had its financial, its political, and its strategic, as well as its engineering aspects. It was capable of closer discussion than it had received, as far as was apparent, from all these points of view. Those who had decided it ought, he thought, to be able to tell them why the mètre gauge was the best to be adopted, and why it should be universal, and precisely where those 10,000 miles were, which had been included, as they were told, in the 'programme'—how many breaks of gauge they would ultimately entail, with existing lines—what amount of traffic and what description of traffic might hereafter be expected to be dealt with, at those points of breaks of gauge. When that information had been obtained or afforded, other questions would also come forward for discussion, namely, 1, whether, if and when 10,000 miles had been constructed on the mètre gauge, it would not be found necessary to convert the 5,000 miles, now existing, on the 5 ft. 6 in. gauge, also to the mètre gauge; and 2, whether the mètre gauge would be a satisfactory gauge to adopt universally throughout such a country. He ventured to suggest that it would be very wise on the part of the Indian Government to reconsider the whole subject, and to do so—not with a foregone conclusion, that what was good for one portion or various portions of the country was good for the whole country—not with reference to an average multiplied by 10,000 to make up an assumed saving in first cost—but after deliberate consideration of the various elements of the case, such as he had indicated, and their detailed application to the different districts in which railways were to be constructed.

Mr. C. E. Spooner, reading from a manuscript, said, that it would appear there were two things that must be the cause of Indian railways not having resulted successfully in a commercial point of view: either the lines constructed had cost too much, or there was not sufficient traffic to pay fair dividends upon capital expenditure. The Paper appeared to point out that the want of success was really due to both those causes. From diagrams which he had made of the comparative difference of the works of a single, and of a double line of railway of the 5 ft. 6 in. gauge and of the mètre gauge, with the same radii and curves for one as for the other—not, in fact, showing the full advantage derivable from the narrow gauge—he had arrived at the conclusion that the proportionate percentage in favour of the mètre gauge, over that of the 5 ft. 6 in. gauge, was 32 per cent. for a single line, and 31 per cent. for a double line of railway.

The cost of the railways, already constructed in India, on the 5 ft. 6 in. gauge—less freight and insurance, telegraphs, stores, rolling-stock, engines, and establishments—amounted to about £11,000 per mile.[1] Taking this cost as a datum, upon the 5,000 miles of railway already made, the 32 per cent. gain in construction, if made on the mètre gauge, or £3,520 less cost per mile, would show a total

[1] Average Cost per Mile of Earthworks, Bridges, Permanent Way, and Stations on the Indian Railways, according to Mr. Danvers' Report:—

	Length reduced to Single Miles.	Cost of Works, &c.
		£
East Indian (main line) and Jubbulpore	1,559	16,355,000
Great Indian Peninsula	1,128	14,672,059
Madras (South-West line)	492	6,117,250
Ditto (North-west line)	185	
Bombay and Baroda	325	4,805,000
Scinde	114	967,129
Punjâb	246	1,025,983
Delhi	174	3,204,535
Eastern Bengal	113	1,960,729
	4,336	49,107,685
Average cost per mile		£11,325

C. E. S.

saving of £17,600,000 to the State. If the 10,000 miles contemplated, were made on the mètre gauge, instead of on the 5 ft. 6 in. gauge, the saving would be £35,200,000; and that would be the minimum difference of cost, without mentioning the advantage gained in earthworks, &c.—by the use of sharper curves through undulating lands and a hilly country—and in maintenance and renewals of permanent way, and by the less wear and tear of the rolling-stock. That total saving of £17,600,000 would be equal to £880,000 annual saving, out of the £1,600,000 that the Indian rate-payer had now to pay. For the 10,000 miles of railway proposed, the annual saving would be £1,760,000, without calculating any gain through greater durability of permanent way or the economy of working the mètre gauge, over that of the 5 ft. 6 in. gauge. It must be admitted by all, that the Indian railways were a commercial failure. The object sought was to obviate a similar failure as regarded the construction of future lines. The making of light railways upon the standard gauge appeared to him to be inconsistent and wrong in principle. The cost of earthworks, bridges, tunnels, &c., to formation-level would be alike in both cases, nor would the supposed economy in lighter engines and rolling-stock be found to succeed.

The Author, after his analysis of Mr. Fowler's estimate and of Mr. Hawkshaw's estimate, assumes the difference in cost between the mètre gauge and the 5 ft. 6 in. gauge in land, earthworks, bridges, sleepers, and ballast would be £1,000 per mile for the contemplated lines in the Punjâb. This amount was less by £2,520 per mile than the minimum difference, he was able to arrive at, according to the above estimates. For economy of construction, and to meet the necessity of opening out the Punjâb, Indus Valley, and Rajpootana districts, it would appear advisable that the lines should be constructed of the mètre gauge throughout; also, that the existing 5 ft. 6 in.-gauge lines between Lahore and Mooltan, and between Kotree and Kurrachee, be converted to the mètre gauge, and the proposed line between Lahore and Peshawur and Mooltan and Kotree be constructed on the same gauge, making a through trunk line, on that gauge, of 1,092 miles. Then there would be the collateral lines from Sukkur to Dadur, and from Sukkur to Rajpootana. The rolling-stock could be drafted on to the 5 ft. 6 in.-gauge lines from off the Lahore and Mooltan railway, and the line from Kurrachee to Kotree. Mr. Fowler's estimate for laying down a third rail between Lahore and Mooltan, and for relaying the line between Kotree and Kurrachee on the mètre gauge, a length of 319 miles, was £327,177, or £1,025 per mile;

so that, on the same data, if two rails were laid down, it would cost £2,050 per mile, while his estimate of £680,000 for the 773 miles gave a saving of only £879 per mile.

It would appear that if a plan was adopted to supply the mètre gauge in the Punjâb and Rajpootana country with a transhipment depôt station at Lahore, a much larger saving could be effected to the state. Supposing that the 773 miles from Peshawur to Lahore, and from Mooltan to Kotree, were constructed on the mètre gauge, and that the 5 ft. 6 in.-gauge lines from Lahore to Mooltan, and from Kotree to Kurrachee were altered to the mètre gauge, the saving would be £2,548,693.

Supposing, on the other hand, that the 773 miles were constructed upon the light system, and the standard gauge between Lahore and Mooltan, and between Kotree and Kurrachee remain untouched, the difference in favour of the mètre gauge would be £1,737,043. He was laying a 2 ft.-gauge line through rather a hilly country, and he did not hesitate to say, that with proportionate curves to those of the 5 ft. 6 in. gauge, the earthworks would cost nearly four times the money.

In regard to the transhipment of traffic, the difficulties were more imaginary than real. With the transhipment junction of the Festiniog and Cambrian railways, where a traffic at the rate of 25,000 tons annually was conducted, but which was laid out for more than double that traffic, the difference in cost over the ordinary junction was £2,740. Of coals, lime, or other heavy material, 2 men could tranship 100 tons in 1 day of 10 hours, or at a cost in wages to the company of 1*d.* per ton from one tipping apparatus, but the charge by the company was 4*d.* per ton, to cover cost of works, land, engines, &c. Timber and goods were transhipped to the extent of 50 tons in 10 hours by 2 men with a crane, or, in wages, about 2*d.* per ton. Of slates, which had to be carefully moved by hand and packed, 4 men could tranship 60 tons in 10 hours; from 3*d.* per ton to 6*d.* per ton was paid when the work was let on contract, on account of the irregularity of the work. The time occupied by passengers in moving from one platform to the other was about 5 minutes. Light goods, from the transhipment warehouse, or from one truck into the other, were changed with rapidity. No compensation, up to the present time, had been paid by the company for damage on transhipment of minerals or goods. A similar transhipment junction at Lahore, upon a more extended scale, might be made, so as to accommodate any possible amount or description of traffic, and it could be furnished with cranes, tipping apparatus, goods-sheds, &c. Had the contemplated lines been but a few miles long, it would have been easy to understand the objections made as to transhipment; but when a whole country of so many thousand square miles, and the great length of the proposed lines, with their full complement of rolling-stock and engines, was considered, the objections could not for a moment hold good, as it practically could only occasion a few hours' delay in the transit of minerals and goods, and of military stores; and passengers would only be delayed a few minutes. The small cost of transhipment and loss of time in transit was too insignificant to be considered, when it was divided over so large a mileage. There would be no change, from one gauge to the other, of stores and passengers for the whole of the North-Western provinces, excepting at Lahore, and probably a large military depôt would be established at that point by the Government.

Lord Lawrence said he would not attempt to enter into the vexed question of the relative merits of the broad, and of the narrow gauges. It was a matter of professional opinion, rather than that of a man trained as he had been; but this he could say, that—bearing in mind that hitherto there had been in India a broad gauge—he thought, as a matter of convenience, they ought to continue the broad gauge, unless there were strong reasons to the contrary. Nevertheless, he was bound to say, he thought there were strong reasons for further consideration. He believed, as a matter of fact, they ought to consider the question of cost rather than the question of convenience. A gentleman had stated to the Meeting that he could make a railway, on the Madras coast, on the broad gauge very nearly as cheaply as he could make one on the narrow gauge. There might be peculiar circumstances which would enable him to do something of the kind; but, as far as Lord Lawrence's experience went—and without aspiring to professional knowledge on the subject, he might say he had some experience of the matter, and had studied it—he believed it was quite out of the question that they could make a railway on the broad gauge, with anything like the cheapness they could make one on the narrow gauge. He preferred judging of the future by the experience of the past. Something like 5,000 miles of railway in India had been constructed on the broad gauge, and these 5000 miles had, in round numbers, cost £90,000,000 sterling; therefore about £18,000 per mile had been spent upon these 5000 miles. He had never heard any engineers say that they could make a railway on the broad-gauge principle under £10,000 per mile; and he believed, as regarded the Mooltan line, the estimates were something like £12,000 per mile. On the other hand, he understood that the portion of that railway which was to be made on the narrow gauge could be constructed for £7,000 per mile. That was called the missing link between Mooltan and Kotree, and was something like 450 miles in length. In the case of the broad gauge then, it might be assumed that the estimate was £12,000 per mile, and in the case of the narrow gauge £7,000 per mile. On the 450 miles the extra cost of the broad gauge would be something like £2,500,000 sterling. Then taking the upper part of the line, from Lahore to Peshawur: the difference in cost was £1,500,000; so that on the whole line from Peshawur to Kotree between the broad gauge and the narrow gauge there would be a difference of something like £4,000,000 sterling.

It was scarcely necessary to say that India was a country with an enormous area; it was, moreover, a poor country. Its great wealth was its agricultural produce. There was not much doing in the way of mining operations. There was not much in the way of manufactured goods to carry; what would be carried on that railway, in particular, would principally be agricultural produce. The lines they had hitherto made in India were the main lines; for the most part they were through the richest and most fertile and best populated parts of the country. Now it was notorious that those lines, having regard to the capital expended upon them, did not pay. Some of them would in course of time, no doubt, do so; but a large portion would perhaps never pay at all. Now, bearing this in mind, it followed that the tracts of country through which the new lines would go were, by comparison, poor; and if the main lines, at their high cost, did not pay, the branch lines in the poorer parts of the country would have a still less chance of paying. The only chance of their making an adequate return would be by constructing them in the cheapest and most economical way, consistent with efficiency.

Now, if he could show that the line from Peshawur, down to Lahore, and from Lahore down to Kurrachee and the sea, would not suffer, as a railway, from a break of gauge, he thought it would follow that a break of gauge might be permitted in other parts of the country. The line he had adverted to was notoriously made for a considerable extent for military purposes. From Lahore to Kotree the country was badly cultivated; it was in many places a wilderness. The population was sparse, large tracts were desert. The line of railway from Lahore to Kotree had to compete with the River Indus, which, he need hardly say, in its downward course was quite sufficient for the transit of agricultural produce. Now it was quite hopeless to expect that line to pay a dividend for many years. If it paid as much as its working expenses, for the next eight or ten years, it was as much as they could reasonably expect. The only traffic of commercial importance, going up the river, would be in piece-goods, with regard to which break of gauge would not be very important; but, bearing in mind that it was mainly a military line—and, but for military considerations, it would not be constructed—he maintained that a break of gauge was of no real importance. They could not, in India more especially, nor, indeed, he submitted, in any country, carry considerable bodies of troops through long distances without rest and refreshment. On the other hand, there was no objection to carrying stores and supplies for an army through hundreds of miles continuously. But if their military arrangements were worth anything, they were so arranged as to bear the press of a great demand for a certain time. A matter of a day or two was of no importance as to stores and supplies, which would be accumulated in suitable positions, in depôts in the vicinity of an army on the frontier; but with respect to troops, they must have places for rest and refreshment along the line of a railway; and they could make the resting places where the break of gauge occurred. Where would be the breaks of gauge? Kotree would be one, Mooltan would be another, Lahore would be another. Those were the places where the troops would stop. Moreover, if an emergency arose, the troops would be sent on from place to place, and one detachment would be gradually following up another; so that, in point of fact, whether they regarded the troops, or the stores, or the supplies, there could be no sensible disadvantage in break of gauge at those points he had mentioned. He did not say that circumstances might not occur in which they might wish to send troops more or less quickly to the frontier; but he could scarcely conceive a state of things where really and truly the moderate rate of 100 miles or 150 miles a day in the movement of troops could not do all that the circumstances required. They did not make railways for what might happen once in twenty years, or thirty years, or in the life of a man; but they made them to meet the ordinary wants of the country. He was convinced that—notwithstanding certain disadvantages and inconveniences, which he admitted to be attendant upon a break of gauge—the railways on the narrow gauge would be quite sufficient for all the real requirements of the frontier; and he thought that to do more than that would be really and truly a waste of money.

Now, he was aware, that what he had said would not be very acceptable to some of his audience. He believed most of them were Engineers, and, without intending to say a word of disparagement to the profession, he thought it was only natural that Engineers should wish to have the best, and most complete, and most effective railways that could be made; and that perhaps, in doing so, they were in some degree—he would not say regardless—but that they did not give sufficient consideration to the question of expense. He thought the Engineer, on such a question as this, should certainly be heard. Much which he had to say was worth hearing, and what he did say should be borne in mind. Regarding this question of a break of gauge in India, it was a question as much for the financier, the administrator, and the statesman, as it was for the Engineer.

Now, the sum and substance of what Lord Lawrence had said was this—except as regarded the break of gauge, he thought the narrow gauge the best. Let them accept the narrow gauge for the future. If they did that, they might have railways in India which would do an enormous amount of good. They would be able to pay for those railways, and in a moderate time such railways probably would pay; otherwise he, for one, said, have no more railways. If they were to get into debt, and to heap up debt after debt, he thought they would get into great difficulties. He thought it was a wise course to do what he had suggested. At any rate, what he had said he believed; and his feeling was so strong, that he felt bound to give expression to it.

Mr. Juland Danvers said, that looking at the interest which appeared to have been excited by the discussion, it seemed a little surprising, that before this time no Member of the Institution had brought forward a subject which was regarded as of such great and general importance. Perhaps if the question had been raised at the Institution two or three years ago, it would have been met with less prejudice, and with a little less feeling. Those who had come to teach might have felt they would have had more hope of producing an impression, and those who came to learn might have felt that they were more open to receive instruction; but be that as it might, the Institution must feel indebted to the Author for having boldly come forward and confronted the engineering world with his thesis. The Author had divided the subject into two parts, the first having reference to the general introduction of light railways in India, and the second to the application of that system to a particular district. Mr. Danvers proposed, in the few observations he should venture to submit, to confine himself entirely to the question of the introduction of light railways in

India, feeling that the application of the system was a matter which must of necessity be left to the responsible government of that country. He would ask them for one moment to look at a map of India, and to consider the immense area of the Indian Empire, and also its great resources, and further to trace out the lines of railway which now existed there; and he thought everybody who had any knowledge of the country would at once admit that it was at present but ill provided with railways. Its great want was internal communication. Its resources were large. Its agricultural products, as Lord Lawrence had stated, were the chief staple of the country; but these could not be brought to market for want of proper means of communication. Cattle draught upon ordinary roads was slow, expensive, and uncertain. Mr. Danvers therefore ventured to hope that this assembly would admit that the introduction of any plan which would rapidly provide for that country a system of communication to be worked by mechanical power, was the correct one to pursue. He did not for one moment mean to contend, upon professional grounds, or with technical weapons, with those engineering giants who had preceded him in the debate. He was ready almost to tremble at the notion of getting into the clutches of that powerful triumvirate who had commenced the discussion, and seemed almost to have governed its subsequent course throughout; but he would ask them to descend from the region of science and philosophy to that of common sense.

He had always been under the impression that size had something to do with expense, and that whether the work were a house, a road, a tank, or an embankment, the cost was always in proportion to the dimensions; but he was met by the observation that this did not apply to railways. In answer to that dictum he would venture to bring forward a few facts which had come under his own experience. One line of railway in the upper provinces of India, the Oudh and Rohilkund, was first laid out for a narrow-gauge line. It was estimated that its cost would be £6,000 per mile. After the scheme had been agreed upon, an alteration took place in the views of the government, and the broad gauge was adopted; the cost of the line, in consequence, became £9,000 per mile instead of £6,000 per mile as originally intended. It might be said that a portion of this expense had been incurred in consequence of heavier rails and heavier materials being employed. He granted it. He allowed £1,000 per mile for that, and yet in this example the saving which would have been effected by using the narrow gauge was something like £2,000 per mile.

Another case occurred in Southern India. The Carnatic railway was laid out and estimated, as for a broad-gauge line; but it was afterwards determined that a narrow gauge should be substituted. The original estimate for the broad gauge was £7,000 per mile; the estimate now accepted was £4,895 a mile, leaving a saving of £1,730 per mile. He admitted that the rails would be rather lighter, and producing in that item a saving of about £600. A line had been constructed in Bengal 27 miles in length, being a branch of the East Indian railway, the cost of which had actually been £3,000 per mile, laid—upon an existing road, he should add—with light rails and suitable for light engines; still it answered its purpose. Mr. Douglas Fox had described a line in Canada which had been constructed for £2,400 per mile. That was just the kind of work wanted in most of the districts of India, and why should they not have it there? But Mr. Danvers could bring forward a case where a line at lower cost even than that, had been constructed in India. Mr. Barnett informed him, that when he contracted to construct a portion of the Madras railway, he, for his own purposes, laid down a short line from the main line to certain quarries and depôts with a view of obtaining materials for his work. The line so laid down on the 3 ft. 6 in. gauge was stated to have cost only £2,200 per mile. This, again, was the description of railway which, while probably rough, as well as light, was suited for many districts in India.

Believing, therefore, as he did, that the extension of the railway system in India was much needed; that in most districts the traffic would be accommodated by light narrow-gauge lines; that there would be considerable saving in the construction and working of such lines as compared with broad-gauge lines; that a greater extent of railway communication might be established, than if the broad gauge were adopted, Mr. Danvers came to the conclusion that, notwithstanding the break of gauge involved, the Government was right in introducing light railways on the narrow gauge into India. He did not wish, for one moment, to dispute the disadvantages, in certain places, of a break of gauge; but he did think that the absence of those disadvantages might be dearly purchased, and he thought it would be dearly purchased if they attempted, in India, to continue to take a broad system of lines into the numerous districts that required railway communication. He thought India was indebted to the Council of the Institution, for having allowed so much time and attention to be devoted to a question of so much interest to that country. Many Members of the Institution had done excellent service in India. He hoped that they would continue to do so, and that they, and their sons after them, would help to promote the prosperity of that country, by taking part in the extension of the railway system upon the cheapest possible principle.

Mr. Vignoles, Past-President, said he would not have pretended to enter into this discussion, which had been so ably sustained, and, in fact, upon every point nearly exhausted, by those who had preceded him; but it so happened—and he supposed the fact was unknown to most of the gentlemen present—that more than thirty years ago, when the mere idea of making railways in India was laughed to scorn, he was engaged by leading gentlemen of the East India Company to investigate the desirability and possibility of making railways in India. On that occasion he wrote an elaborate report, and he would ask permission of the Council to have it printed in the Appendix.[1]

In that report he laid down certain leading principles and arguments, and, on looking at it again after the lapse of so many years, there was scarcely one word of those principles or arguments which he would now retract. One of the chief reasons he had for asking that it might be published in the Minutes of Proceedings was to controvert the observation made that engineers, and the members of the Institution in particular, looked to the glorification of themselves and to the magnificence of their works.

The whole argument of his report was "economy." He therein demonstrated that railways might very well be made in India for £8,000 per mile. This report was filed in the records of the East India House; but when that building was taken down there were some three hundred tons of valuable documents disposed of to the paper-makers, and he thought it possible that this report might have been amongst them.

The report, however, was published in the Bombay newspapers in 1843 and 1844, and was commented upon by the eminent Dr. Buist. Subsequently—when Mr. (now Sir) Macdonald Stephenson had urged the question in India and in London—a London Board of Directors issued a prospectus, inviting subscriptions for an East Indian railway, and Mr. Vignoles was appointed Engineer-in-Chief. This post he resigned in consequence of his having been honoured by Lord Dalhousie with the offer of becoming the leading member of a commission, then about to be established by his Lordship, to study the question of railways for India; and, subsequently, the late Mr. J. M. Rendel, Past-President, became his successor in the private company.

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[1] *Vide* Appendix II.

Circumstances occurred which broke off the negotiation with Lord Dalhousie, of which he would only say that the failure left no reproach on him, though the opportunity was lost for carrying into practical effect the suggestions made, and the principles laid down in his Report.

It was probable that General Strachey had never heard of this report, nor of the report made by the Irish Railway Commissioners. It was quite evident that neither the Author nor Mr. Danvers, nor any of their predecessors in office, could ever have heard of these documents; for there was not a recommendation with respect to the Irish railways which was not applicable, word for word, to India, and there was not a single suggestion in the report which had not been stultified and ignored by those who had undertaken to manage the railway affairs of India, or had carried out the railway system in that country, whoever they might be. Far from allowing any gentleman to say, uncontradicted, that it was wrong for any one in this room to suggest, that what the Government ought to have done now, was to have taken the advice or to have consulted the opinions of the Institution of Civil Engineers, Mr. Vignoles said, that if the Indian Government had done so thirty years ago they would have far better benefited that country, and would have been in a very different position on the question of railways to what they now were.

One of the leading principles repeatedly laid down by the Irish Railway Commissioners was, that, before railways were carried out, as a system, in a new country, the greatest care should be taken in the first instance that those lines which were profitable should be made to pay for those which were not profitable; whereas, by the way in which the railways in India had been unsystematically carried through, the chief profitable lines presenting openings had been executed, under a guarantee of interest from the Government. Mr. Vignoles ventured to say that the advisers of Government had been unfaithful trustees, and General Strachey, Mr. Thornton, and Mr. Danvers, or whoever the trustees for the time were, had been false to that trust. Their trust was, from the beginning, to have studied the question on a much larger basis than those gentlemen appeared to have done. The representatives of the Government had no right to throw in the teeth of the English engineers that it was necessary to be acquainted with all the details of Indian circumstances to judge of a question like this, since they, as trustees, had shown themselves ignorant or neglectful of these very details. This was a great, a national question, which had not been treated as it ought to have been, for the action of the Indian Government, under bad advice, had left the remoter parts of India in such a situation that the State could not afford to make railways through them, because they had not previously sufficiently studied the resources of the country.

Mr. Vignoles trusted his declaration would be accepted, that it was not of the slightest interest to himself, personally, how the question before the Institution was resolved by the Government. Until the Paper was read he had almost forgotten, for thirty years, either the subject of railways for India, or the consideration of the break of gauge in any country; and he fancied he must have been asleep during that long period, when he was roused up and informed that Indian railways, instead of having been constructed for £8,000 per mile, had really cost £18,000 per mile, and that it was proposed to obviate this extra cost, for the future, by breaking the uniformity of gauge, now spread over a network of 5,000 miles, and thrusting in a narrow gauge of one mètre! And what was this crotchet of a mètre? Was it to insert the thin end of the wedge, and to make a bold step for introducing the whole metrical system of weights and measures into India, as built up on a 'soi-disant' scientific basis? If the Government advisers thought the mètre was a scientific unit they were quite mistaken. It was a mere arbitrary unit, for it had been demonstrated at least twenty years since that the conclusion arrived at by the French philosophers towards the close of the last century, namely, that the mètre was exactly some few millionths part of the quadrant of the terrestrial globe was erroneous, and thus the scientific basis of the mètre vanished. As an Engineer, Mr. Vignoles asserted that the assumed saving of £1,000 per mile was illusory. He maintained that without breaking the present gauge they could have cheap and light railways in India, a necessity which the Government advisers had found out, at last, after twenty-five years of 'meddle and muddle,' and such railways the Government might have quite as efficient, and quite as cheap, within a few hundred pounds per mile, upon the present gauge, as upon the mètre gauge. Though he had prepared ample notes for the purpose, he would not now enter into details. It had been already much better and more effectually demonstrated by others, than he could have done, how absurd and how detrimental the proposed change of gauge would be, and in how little additional cost the retention of the present gauge would really involve the Government.

The consideration of cost led him to observe that, if the difference between the interest guaranteed by Government to private companies and the actual net returns from the railways did really fall, as a tax, on the great mass of the population, that was on the agricultural class, certain curious questions arose. Had not railways contributed to increase the land revenue of India to the great extent it had swollen to? Had not the districts pervaded benefited enormously? Would not the construction of roads, converging on to the lines of railway, have increased the traffic? and why had not such roads, as feeders, been made? Whose duty was it to have made them? and so on. He would quote his report before alluded to:—"Without observing further on the policy of the East India Company, it may be remarked, that little or rather nothing has been done by them for India for the true development of its resources; since easy means of internal communication—the very first step necessary to effect this object—have never been attempted until very recently indeed; and were the whole projected system of railways unconditionally undertaken by the company, it would be but a tardy fulfilment of long-deferred obligations which their claim of seignorial dues on the land requires of them. That 'property has its duties as well as its rights,' is equally true in India as in Ireland; and quite irrespective of the political colour which was given to that aphorism."[1] An article in the "Athenæum," written several years previously, said:—"A nation may wisely spend money upon other considerations than those which govern a private capitalist."

He would ask what was the state of the roads of India in 1840? He would answer:—In the four collectorates adjacent to Bombay, over 30,000 square miles, an area larger than Ireland, there was only one mile of metalled road for every 50 square miles; and during the rainy season, that is during a third of the whole year, only one mile of road practicable for carriages to every 300 square miles of territory. It was no better, and often much worse, over every other part of India, where the towns and posts of the interior were so many isolated spots during the rains, and however important it might be, either in a military or commercial sense, it was impossible to pass carriages along the roads such as they were.[2]

And so the roads remained, at the present time—the interest being guaranteed to the private companies, they would not make roads as feeders—and the only way for the government to re-coup their annual loss of one and a half million must be to make those feeders themselves.

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[1] *Vide* Appendix II., § 96.

[2] *Vide* Ibid., §§ 34, 35.

Before concluding, Mr. Vignoles referred to an able report, in the Archives of the Institution, written in the course of the summer of 1872, by Mr. Walton W. Evans, of New York, one of the most distinguished Engineers in America, in reply to a request from the Agent-General of the British colony of Victoria, to furnish information for the guidance of the government there on the subject of the narrow gauge for railways. This report was most instructing and exhaustive, and recommended itself to the notice of all interested in the present question. The substance was decidedly conclusive against the narrow gauge, for very sufficient reasons assigned, and this was stated to be the opinion of every leading engineer in the United States.

Major-General Strachey, by permission of the President, and in explanation, said, that no doubt Mr. Vignoles had brought a great many valuable facts before the Meeting; but that gentleman had mixed up with his facts a certain quantity of statement, which he never would have thought of making if he had been connected with any of the guaranteed railways of India. If that gentleman had been Engineer of any of the guaranteed lines he would never have associated General Strachey's name with the guarantee of Indian railways; he never would have said that he upheld such a financial policy, or that he had been anything but the consistent, and some gentlemen might say the bitter, and even offensive, opponent of that system; therefore he accepted no responsibility for anything that had been done in connection with railway guarantees in India. What, in fact, he had been doing for many years, was to try to obviate the evils that had arisen from that system; and he was in that unfortunate position, that the evils which had arisen from a system of railways, thoroughly incompatible to the country, had now to be corrected, and he was the unfortunate person to bear the brunt.

Mr. J. Brunlees read the following observations, and stated, that, as he was not in any way connected with the construction of railways in India, what he had to say on the question before the Meeting was without bias. He had, however, constructed lines on the 3 ft. gauge, the mètre gauge, the 1·1 mètre gauge, the 3 ft. 6 in. gauge, the 4 ft. 8½ in. gauge, and the 5 ft. 3 in. gauge; and he might, therefore, safely say he was not wedded to any one to the exclusion of all others. His opinion was that the gauge was a question of circumstances, and that where it would be wisdom, in one case, to lay a certain gauge, it would in another be the height of folly. Generally speaking, he was in favour of a narrow gauge, say the mètre gauge, for the development of thinly populated countries, and he would illustrate his meaning by reference to a country with which he had had a great deal to do, namely, Brazil. The first railways constructed there, were on the model of the best European lines, to a gauge of 5 ft.3 in., and their average cost per mile had been more than £20,000. When some 500 miles of line had been constructed at that rate, the Brazilian government reconsidered the whole question, and, he thought wisely, resolved that all future extensions should be on the mètre gauge. The Brazilian empire contained an area of nearly 4,000,000 square miles, with a population of 10,000,000, or $2\frac{1}{2}$ persons per square mile; and it was obvious that if the interior was to be opened up and its great natural resources developed by railways, it must be by means of lines costing much less than £20,000 per mile. By adopting a cheap system of construction, he found that lines of a mètre gauge could be made in Brazil for from £6,000 per mile to £7,000 per mile; and such lines, worked at moderate speeds, and without expensive station buildings and appliances, had met all the requirements of the country. As regarded the lines constructed in Brazil on the broad gauge, he was of opinion that before long it would be found necessary to reduce them to the mètre gauge. It was not more than two years since the mètre gauge was adopted, and many of the lines in course of construction on it started from the coast, and had no connection with the broad-gauge lines, therefore the evils of a break of gauge had not yet been experienced; but, without doubt, they would eventually be experienced, when the Brazilian railway system became further developed. In saying this, he must not be understood as laying down the principle, that a break of gauge was never allowable, but merely that in the case of Brazil, where the mileage of broad-gauge lines constructed was so small, in proportion to that of the narrow-gauge lines which had to be made, it would be absurd not to have uniformity of gauge.

He came now to the question more immediately before the Meeting, and he spoke with some diffidence on it, from not being personally acquainted with India. Still there were facts that were patent to all, and it was on those he should rely. India was little more than one-third the size of Brazil, and its population was between 110 persons and 120 persons per square mile; it required, therefore, much greater facilities in the way of railway communications than those which were proportionate to the requirements of the sparse population of Brazil. His opinion therefore was that both the broad gauge and the narrow gauge were required in India, but under different conditions from those which had hitherto been brought before the Institution.

It was not his intention to go into the question of the relative cost of the broad-gauge lines and of the narrow-gauge lines in India to the extent that had already been done by Mr. Bruce and others. The 5 ft. 6 in. gauge, he thought, would now be admitted to have been a mistake in the first instance, and that, had a somewhat lighter type been adopted, say the 4 ft. 8½ in. gauge, there would not have been any necessity for discussing the advisability of introducing the mètre gauge. His objection to the 5 ft. 6 in. gauge was that it was altogether too heavy for the requirements of a country where the traffic was not concentrated, but had to be picked up in small quantities from numerous stations on a long length of railway. Wagons weighing, when empty, nearly 6 tons were employed in carrying a few bags of grain or logs of dye-wood, or other produce, and the result was that the proportion of the dead to the paying load, carried from and to roadside stations, in India, was excessive. The stations and accessories were, in consequence, on a larger scale than was necessary, while the expenses of the staff were swollen by the number of porters required for shunting and moving the heavy stock about; the locomotive expenses and maintenance being also increased much out of proportion to the traffic conducted.

Five thousand miles of the broad gauge, however, existed, and no one, with the exception of Captain Galton, had the boldness to suggest that they should be in any way interfered with. Mr. Brunlees accepted them as an unavoidable evil, and, in spite of the disadvantages he had enumerated, he was decidedly of opinion that the broad gauge should remain the standard gauge for the railways of India, and that the whole of the seaports, and the chief military stations and commercial centres of the country, should be connected by lines of that gauge. On lines still to be built a saving might, however, be effected by judicious economy in construction. The permanent way might be made somewhat lighter; expensive buildings at stations might be avoided; and, above all, a lighter rolling-stock might be introduced. By these means their cost would be brought nearer to that of the mètre-gauge lines proposed by the Government, and the immense evil of a break of gauge on the main lines or trunk lines of the country would be avoided.

As regarded the mètre-gauge lines, he thought that they should be laid out merely as feeders to the railway system of the country—in fact, taking the place of roads—and should therefore be constructed upon a diminished scale to that proposed by the Government. They should partake more of the character of steam tramroads. The rails should weigh not more than 30 lbs. per yard;

the engines from 8 tons to 10 tons, and the wagons $1\frac{1}{4}$ tons empty, with a carrying capacity of 3 tons. The passenger carriages should weigh about 2 tons, and be equal to the accommodation of 20 people. Finally, the speed should not exceed from 10 miles per hour to 15 miles per hour. This might seem a low rate, but it must be remembered that the lines would be used almost exclusively for goods, and by natives, to whom 10 miles a day was now the ordinary rate of travel. No station buildings, beyond sheds, would be needed; and lines of the description he had sketched might, he estimated, be constructed at an average cost of about £3,500 per mile. In short, he believed that, by adopting a plan such as he had suggested, of a system of narrow-gauge lines or tramways, acting as feeders to the main system of broad-gauge railways, these latter would in a very short time pay the guaranteed rate of interest, and the feeders would return a much higher percentage.

Before concluding his remarks, he must make a few observations with reference to the proposal of the Government to construct the Indus Valley railway as a narrow-gauge line. He thought, with the previous speakers, that it would be a grave error to carry out that proposal, the consequences of which it was impossible to estimate.

The Indus Valley railway would, unless the line from Ajmere to Sukkur were constructed, be isolated from the remainder of the proposed narrow-gauge system, and no interchange of stock in cases of emergency would be possible; and it was evident, from what Mr. Lee Smith had said of the nature of the country through which the Ajmere-Sukkur line would pass, that such a line would scarcely pay its working expenses. This being so, the cost of its construction should certainly in part be debited to the Indus Valley railway, as the cost of bringing it into communication with the proposed narrow-gauge system. If this were done, the saving claimed by the Government in the construction of the Indus Valley line as a narrow-gauge line would at once disappear, and an excess as compared with the broad gauge would be exhibited.

It appeared to him, therefore, that so far as that line was concerned, the arguments had utterly failed to show that any economy would arise from the departure from the broad gauge; while the proposal to interpose, on one of the most important strategic lines in the country, a piece of isolated narrow-gauge line, was, to say the least, ill-advised. He had known only one similar instance in practice, and in that case the circumstances were of a peculiar character. He referred to the Mont Cenis summit line, constructed upon a narrow gauge, between the French system of railways at

St. Michel, and the Italian system at Susa. The traffic in this case was chiefly passenger traffic, and, though the break was only for a distance of 50 miles, the inconvenience experienced was most serious. To the development of the goods traffic it was excedingly detrimental. Each ton of goods cost 8*d.* in transhipment, and a day's delay, the station arrangements being very expensive and complicated. In fact, if there had been a great amount of goods to deal with; or had an army, with its baggage, commissariat, ammunition and artillery accompaniments, made its appearance, there would have been inextricable confusion. The experience he gained in connection with that line had convinced him that, on all main lines or trunk lines of communication, break of gauge was an evil to be avoided at almost any cost in the construction.

Mr. Sandberg said, he had not any experience of the relative merits of the gauges in India, but he would state what had been done in regard to that matter in Sweden. About three years ago a discussion took place between the railway engineers and some members of the government respecting the continuation of the gauge adopted in that country, owing to the railway, on the standard gauge of 4 ft. 8½ in., being considered too expensive. The arguments on both sides were so equally balanced that no decision was arrived at, and the result was that the standard gauge was continued, but the cost was reduced by a lighter construction, which necessitated a lower speed. The main lines had been kept up to the same gauge, and there were about 107 miles of narrow-gauge lines now open. Taking the average cost of the 4 ft.-gauge lines and the 3 ft. 6 in.-gauge lines, the cost of those lines was about £500 per mile cheaper than the 4 ft. 8½ in.-gauge lines with light construction. Railways of the same gauge with heavy construction and adapted for higher speed had cost £7,000 per mile. There had been considerable discussion whether it was advisable to change the gauge to 3 ft. 6 in. He was aware what their neighbours in Norway were doing and while they were converting some of their 4 ft. 8½ in.-gauge lines into 3 ft. 6 in.-gauge lines, the reverse was being done in Sweden. He might state that the opinion of the Swedish engineers generally was, that they had no reason to regret the step they had taken. Great improvement had taken place in the traffic, and from the discovery of coal in the south of Sweden, a large traffic was anticipated, and perhaps the single light 4 ft. 8½ in.-gauge lines would not be sufficient. There was now very little support given to the narrow gauge, in Sweden, and lines which had been proposed on a 3 ft. 6 in. gauge had generally been executed on a 4 ft. 8½ in. gauge. He had recently published a complete "Account of the Swedish Railways, their Cost, Gauge, and Speed;"[1] a few extracts from which, he thought, might form a useful portion of the Appendix.[2] In conclusion, he wished to state, that he had received a communication from Baron von Weber, M. Inst. C.E., who was an eminent authority, giving his opinion not only on the gauge question in Sweden, but also on that subject for extensive application in Austria, to the following effect:—

"I am exceedingly obliged to you for forwarding me your Report on Swedish railways as to cost, gauge, and speed, and I now beg you to allow me to translate it into German, and add my remarks.

"It comes in very well for me now, as I have formed a Company with large capital for the construction of branch lines in Austria, on the normal gauge of 4 ft. 8½ in., constructed in the most economical manner, and worked at a speed of from 10 kilomètres to 14 kilomètres only. I am at present engaged in enforcing the laws which free railways of this class from all the regulations of traffic and municipal supervision, by which the cost of construction and working is considerably increased.

"Austria, with her mountains and immense agricultural production, is just the country for such railways, and I think I shall be right in carrying out your plans on a large scale. Your Report confirms thoroughly the opinion I have expressed to my Government, and I shall therefore lose no time in publishing it in German, of course giving your name."

Mr. R. Price Williams, speaking from copious notes, said, he should have thought, before hearing the speech of General Strachey, that the estimates brought forward by the Author were rather of a corroborative character, in support of the more detailed and exact estimates upon which, it was to be presumed, the Government had arrived at the grave conclusion to alter the gauge in India. He found, however, he had been mistaken, and that the estimates, if they could be called such, which General Strachey had brought forward in support of the figures given in the Paper, were, if anything, of a more general and vague kind. He gathered from what General Strachey said, in commencing his remarks, that, to some extent, he discredited the Author's assumption of the saving of the narrow gauge, with the qualification that this did not disturb the general conclusions arrived at by the Government; but shortly afterwards he rejected altogether the Author's figures as wholly inapplicable, but still he

[1] *Vide* "Engineering," February 21, 1873.

[2] *Vide* Appendix III.

asserted that the financial advantage secured was great—that it justified the conclusions of the Government. General Strachey then gave his own views of what was likely to be required on an Indian narrow-gauge line, and said, that if mètre-gauge lines, as now constructed, were not able to carry the traffic, the whole argument in their favour failed; while, further on, he affirmed that the narrow gauge was able to carry anything that could be brought on it.

Mr. Price Williams had understood that the chief argument in favour of the adoption of the narrow gauge was, that it provided a means of carrying traffic in localities where the amount was so limited as not to justify the use of ordinary railway plant. So long as the traffic was of that limited character, he considered there would be full justification for its adoption; he would, for instance, suppose the adoption of it in such a country as Norway, where the population was extremely sparse, and where the loads per train were half those of an ordinary-gauge line, in other countries. It was clear, in that case, that rails, sleepers, ballast, weight of engines, &c., must be proportionally reduced; in fact, the line would become, in every respect, a sort of model of the broader gauge to scale, with half traffic to carry. Such lines, in fact, were the admirably designed, and no less admirably constructed lines described by Mr. Carl Pihl; and he could not help regretting that he had not the opportunity of explaining, as he would have done, that he was in no way the advocate of the views which General Strachey put forward, or that narrow-gauge lines constructed for a very limited amount of traffic, such as he had referred to, were at all equal to carry the large traffics of standard-gauge lines. Directly it was contended that these miniature railways could carry any traffic that was brought upon an ordinary-gauge line, the whole argument in their favour completely broke down. In the first place, the weight of the rails, the scantling of the sleepers, the bearing surface on the ballast, and the power and number of engines must be increased to the full proportion required on the broad gauge. The number of vehicles must similarly be increased, and disproportionate running expenses must be incurred.

It had been estimated by General Strachey that the saving to be anticipated from constructing the Lahore-Peshawur line with rails weighing 40 lbs. per yard instead of 60 lbs. per yard, was from £1,000 per mile to £1,500 per mile on the permanent way; 30 per cent. to 40 per cent. saving in cost of ironwork of bridges, besides minor economies of all sorts, which he considered it unnecessary to mention; and he gave, as the total saving on the permanent way of the Lahore-Peshawur line, £350,000, and on the bridges, £280,000;

or say, on the whole, £750,000. The saving on the permanent way of the Indus Valley line he estimated at £500,000, and probably, he said, as much more on other items, making altogether on the Indus Valley a saving of £1,000,000; which, with the saving on the Lahore-Peshawur line, made a grand total of £1,750,000; deducting a round £500,000 for breaks of gauge, it left a total net saving, as General Strachey said, of £1,250,000. Now, it would be seen, that of this estimate £850,000 represented the saving on permanent way alone—£1,300 per mile on the Peshawur line, and about £1,042 per mile on the Mooltan-Kotree line. These figures, General Strachey said, did not take into account the greater economy of maintenance of the narrow gauge, which would probably be in proportion to the greater economy in the first cost.

Now Mr. Price Williams begged to dispute the assumption of greater economy in maintenance. General Strachey, after stating he did not think he was entitled to take it, nevertheless availed himself of this assumed saving in maintenance, on Mr. Hawkshaw's basis, raising the whole amount of saving to about £2,000,000 sterling; £1,600,000 of this was due to saving in construction and maintenance of permanent way, namely, £350,000, permanent way of the Peshawur line; £500,000 ditto, Mooltan-Kotree line; and £750,000 saving in cost of maintenance on both the above lines.

It would not fail to be noticed, that in the estimates both of the Author and of General Strachey, after all, the great bulk of this enormous saving was in the matter of permanent way; and it would be seen that General Strachey's estimate was largely in excess of those given in the Paper.

Returning to the Paper, he demurred entirely to the correctness of the axiom laid down at the outset, that the broad gauge was never adopted except with broad, heavy vehicles, and that on narrow lines comparatively light vehicles were used. Mr. Hawkshaw, upon whose estimates the Author professed to rely, expressly stated in his Report:—"That a very large saving of £2,050 per mile would be obtained by the adoption of a lighter form of engine and a lighter construction of road on the standard light gauge as compared with the standard heavy gauge lines." Mr. Harrison had further drawn attention to the fact that in England there were many lines of that description, and instances could be largely multiplied.

Mr. Price Williams was about to construct a light railway on the standard gauge in the west of Ireland, the circumstances of which he felt had a direct and practical bearing on the subject under discussion. The Irish gauge, as was well known, was very similar to the Indian broad gauge, namely, 5 ft. 3 in. The line alluded to was about 50 miles in length, and for the greater part a surface line. Its sharpest curve had a radius of 10 chains; its steepest gradient was 1 in 60. It traversed a thinly-populated district, with a small traffic of about £7 per mile per week, necessitating its construction on the lightest possible scale consistent with efficient working. Impressed with this necessity, its promoters consulted him upon the advisability of constructing it on the narrow gauge, and he accordingly prepared estimates for a light line on the 3 ft. 6 in. gauge, with 40-lbs. rails, as follows:—

IRISH RAILWAYS.

Comparative Cost per Mile of 5 ft. 3 in. Gauge and of 3 ft. 6 in. Gauge.

——	5 ft. 3 in. Gauge.	3 ft. 6 in. Gauge.	Saving by 3 ft. 6 in. Gauge.	Percentage of saving on total saving.
	£	£	£	per cent.
Land	55·20	52·39	2·81	1·35
Earthwork	757·90	661·98	95·92	46·33
Permanent way.	1,081·33	995·25	86·08	41·58
Ditto sidings	26·40	26·40	..	..
Bridges and culverts . . .	83·59	80·18	3·41	1·65
Telegraphs, level crossings, metalling and fencing . .	489·13	489·13	..	..
Stations	145·30	145·30	..	..
	2,638·85	2,450·63	188·22	90·91
Contingencies 10 per cent. .	263·88	245·06	18·82	9·09
	2,902·73	2,695·69	207·04	100·00
Deduct for additional cost of renewals of permanent way per annum capitalized (*vide* Table, p. 342)	..	..	267·41	
Balance in favour of the 5 ft. 3 in. gauge	..	..	60·37	per mile.

He would not trouble the Meeting with the details of these estimates; it would suffice to state that they showed a saving per mile on the narrow gauge of £207, or 7½ per cent. on the total cost of construction, which was very much about the amount of saving which Mr. Bruce mentioned as having been estimated in the case of a light railway in India. Of this total amount of saving, a little more than 1 per cent. represented the saving in land; 46 per cent. in earthwork; 41 per cent. in permanent way, and about 1½ per cent. in bridges; the latter being few and unimportant. With regard to the 41 per cent. saving in permanent way, the principal item was the saving in sleepers. He adopted for the narrow gauge the scantling of sleepers given in Mr. Fowler's estimate for the Mooltan-Kotree line, namely, 9 in. × 4½ in., in order to show the largest possible saving that could be calculated upon. He prepared also the following estimate of the relative cost of maintenance and renewals on both gauges:—

IRISH RAILWAYS.

Comparative Cost of Maintenance and Renewals of Permanent Way upon the 5 ft. 3 in. Gauge and upon the 3 ft. 6 in. Gauge.

—	5 ft. 3 in. Gauge.			3 ft. 6 in. Gauge.		
	Cost per mile.	Life.	Annual Cost of Renewals.	Cost per mile.	Life.	Annual Cost of Renewals.
	£ s. d.	yrs.	£ s. d.	£ s. d.	yrs.	£ s. d.
Rails (42 lbs.)	598 10 0	25	23 18 10	598 10 0	25	23 18 10
Fish plates	52 10 0	25	2 2 0	52 10 0	25	2 2 0
Fish bolts.	17 10 0	25	0 14 0	17 10 0	25	0 14 0
Spikes	31 10 0	10	3 3 0	31 10 0	6	5 5 0
Sleepers:—						
8 ft. 6 in. × 9 in. × 4½ in. .	205 6 8	10	20 10 8	..	..	..
6 ft. 9 in. × 8 in. × 4 in. .	..	..	..	132 0 0	6	22 0 0
Ballast:—						
Top	44 0 0	10	4 8 0	37 12 6	6	6 5 5
Bottom	44 0 0	..	..	37 12 6	..	..
Labour to renewals:—						
Rails	44 0 0	25	1 15 2	44 0 0	25	1 15 2
Sleepers	44 0 0	10	4 8 0	44 0 0	6	7 6 8
£	1,081 6 8		60 19 8	995 5 0		69 7 1
Labour to ordinary maintenance, packers, &c. . .	..	..	36 0 0	..	..	41 0 0
		£	96 19 8		£	110 7 1

Annual Cost of Maintenance and Renewals of Permanent Way.

	£ s. d.	
3 ft. 6 in. gauge	110 7 1	
5 ft. 3 in. gauge	96 19 8	
Extra cost of maintaining the 3 ft. 6 in. gauge	£13 7 5	per annum.
Twenty years' purchase of	£13 7 5	= £267 8*s*. 4*d*.

The extra cost of maintenance and renewals on the narrow gauge was £13·37 per mile, which, capitalised at 20 years, represented £267 8*s.* 4*d.*; the saving in cost of construction, as already explained, being £207, leaving a balance against the narrow gauge of £60 per mile. He should state that the cause of the increased cost of maintenance and renewal on the narrow gauge, under similar conditions and amount of traffic, was entirely owing to the smaller scantling of the sleepers, and for the following reasons. The life of rails, as was well known, was measured by the tonnage and the speed, or 'speed tons,' as they were called. The same held good as to the life of sleepers. The additional element of the natural decay of the wood had also to be taken into account. Assuming the amount of traffic to be the same on both gauges, it was evident that the life of the rails would be the same; and assuming the scantling of the sleepers on the narrow gauge to be smaller than that of those on the broad gauge, and the amount of traffic in both cases to be the same, it followed that the life of the sleeper of the smaller scantling would be the shortest. The life of a common larch sleeper, of the scantling referred to, was 10 years for the larger sleeper, and 6 years for the smaller sleeper. The smaller scantling sleepers, as was usually the case, consisted of the top portions of the trees, and the wood was consequently more sappy and perishable. It followed, therefore, that under a given amount of traffic, any reduction of scantling of the sleepers was necessarily attended with additional cost of maintenance and renewal of way, as renewals were more frequently required. The natural inference to be drawn from all this was, that it really was more economical to use the better and costlier material, even for these narrow-gauge lines. It was obvious, if the smaller scantling would do for the narrow gauge, it would do for the broad gauge under a similar amount of traffic. It might be argued that the broad gauge required a sleeper 2 ft. 3⅝ in. longer than the mètre gauge. That was not so, as the bearing surface upon the ballast was proportionate to the load carried, and quite independent of the gauge; consequently, what was a sufficient bearing surface in the one case was absolutely necessary in the other: for instance, if there was a longer sleeper in the one case, it was essential to have a broader one in the other. There was this additional advantage in the longer sleeper, that the load was distributed over a wider surface of ballast, ensuring greater stability, and requiring less frequent packing of the road. He would point out what seemed hitherto not to have been referred to, namely, that where longitudinal timber sleepers, or iron pot sleepers were used—and he understood they were being used to

——	Saving per Mile 3 ft. 6 in. Gauge, compared with 5 ft. 6 in. Gauge.			Mr. Thornton's Estimate as adjusted for the Mètre Gauge.	Total Saving on 10,000 Miles of Railway as per Mr. Thornton.	Percentage on Total Saving.
	Mr. Fowler.	Mr. Hawk-shaw.	Mr. Thornton.			
	£	£	£ s.	£	£	per cent.
Land	..	10	10 0	10·1626	101,626	1·02
Earthwork	37	100	average 68 10	69·6138	696,138	6·96
Bridges	83	50	,, 66 10	67·5812	675,812	6·76
Sleepers and ballast, &c.	503*	200	,, 352 0	357·7238	3,577,238	35·77
Sleepers . . . £308						
Ballast . . . 140						
Laying . . . 10						
10 per cent. for Sidings . . 45			497 0			
*£503						
Engineering and agency	87	..	87 0	88·4146	884,146	8·84
Maintenance and renewals of permanent way	..	200	200 0	203·2520	2,032,520	20·33
Add saving by sharper curves in earthwork	..	200	200 0	203·2520	2,032,520	20·32
Total	710	760	984 0	1,000·0000	10,000,000	100·00
Actual average	735					

a large extent in India—there was no saving whatever as between broad-gauge lines and narrow-gauge lines in that respect.

Returning to the estimates—he would draw attention to the Table (p. 344) as showing that the actual average saving was £735 per mile, and not £984 per mile, as was made to appear in the Paper.

What had really been presented in the Paper was a maximum estimate, or nearly so, as might be seen from a reference to the following tabular statement, in which he had given, on the one hand, all the largest items in Mr. Hawkshaw's estimate and in Mr. Fowler's estimate; and on the other hand, all the small items. The maximum estimate of saving was thus shown to be £1,183 per mile, or very little more than the Author's estimate; while the minimum estimate only amounted to £287 per mile; and, supposing the wish to be father to the thought, it was quite open to the Author to have taken the smaller estimate. Mr. Price Williams would particularly direct attention to the fact that, in the estimates both of the Author and of General Strachey, the great bulk of the estimated saving was in the item of permanent way.

It would be seen that the saving in the cost of construction of the permanent way was estimated, by the Author, at 36 per cent.; and in addition to this, a further saving of 20 per cent. was shown in the item of maintenance; making altogether 56 per cent., which would represent considerably more than half of the total estimated saving of £10,000,000.

——	Maximum Estimate. Per Mile.		Minimum Estimate. Per Mile.	
		£		£
Land	Mr. Hawkshaw	10	Mr. Fowler	..
Earthwork	,,	100	,,	37
Bridges	Mr. Fowler	83	Mr. Hawkshaw	50
Sleepers and ballast, &c.	,,	503	,,	200
Engineering and agency	,,	87	,,	..
Renewals of permanent way	Mr. Hawkshaw	200	Mr. Fowler	..
Additional saving, by sharper curves in earthwork	,,	200	,,	..
		£1,183		£287

In General Strachey's estimate, the saving in the cost of permanent way on the Peshawur line and on the Mooltan-Kotree line was considerably higher, amounting, as far as Mr. Price Williams could make out, to 75 per cent. It should be remembered, that the

Author's estimate of saving on the permanent way was entirely dependent upon the adoption of sleepers of the smaller scantling, as given in Mr. Fowler's estimate, the adoption of which must inevitably result in a large addition to the annual cost of maintenance and of renewals consequent upon the shorter life of the sleepers, and, to a certain extent, in extra cost of repairs due to the greater instability of these narrow-gauge lines when subject to similar conditions and amounts of traffic. Mr. Price Williams found, from Mr. Lee Smith, that the life of ordinary sleepers used in that part of India was much about that which he had given. Assuming, therefore, in the Author's estimate, the same scantling sleepers to be used in both cases, this saving in first cost entirely disappeared, and with it, of course, the 20 per cent. saving in maintenance also. He would, at the same time, draw attention to the fact that Mr. Fowler made no claim at all for extra cost of maintenance. No one knew better, indeed, than Mr. Fowler that, under a given amount of traffic, the more lightly-timbered permanent way must necessarily be the more expensive to maintain and renew. With regard to the saving in ballast, all that could possibly be claimed was the saving of the central strip of 2 ft. 3⅝ in., representing the extra width of the broad gauge. As to the 1 ft. 3 in. estimated depth of ballast for the broad gauge, if 1 ft. would do for the one gauge, it was obviously sufficient for the other; and if the sleepers were the same length in both cases —as Mr. Price Williams maintained they should be—that item of saving also disappeared, and with it the entire saving in earthwork, as the width of formation required would then necessarily be the same. With regard to the £45 per mile saving for sidings, the greater number of vehicles would require greater length of sidings, so that there could clearly be no claim under this head. Then there was the item of engineering and agency, which, after the very large deductions he had already made in the total estimated amount of saving, would necessarily be very much reduced also. There now only remained the large item of 20 per cent. saving on earthwork, by having sharper curves and heavier gradients. Mr. Hawkshaw, he thought, had already disposed of that.

Mr. Price Williams would notice, however, that no account had been taken in the estimates for the additional length of line due to these sharper curves, which, if it were taken at only 10 per cent., would amount to an additional cost of £175 per mile on the Mooltan-Kotree line. No claim had been made by the Author, or by the other advocates of the narrow gauge, for saving in respect of the rolling-stock, either in cost of construction or maintenance; all the experience on this subject showed conclusively, that there was no real economy in constructing the framing of rolling-stock on too slight a scale, even for these light lines. He might state he had availed himself of an opportunity afforded him of examining the drawings of rolling-stock for both broad guage and narrow gauge in India, and he had been struck with the exceedingly slight character of the framing of the carriages and wagons designed for the mètre gauge. With the view of satisfying himself on this point, he had been at the trouble of taking out the quantities of timber in each case with the following results:—The quantity of timber in a low-sided truck, of the standard gauge, with a carrying capacity of 338 cubic feet, was 86 cubic feet of timber; while the low-sided truck, of the mètre gauge, on the Indian lines, with a carrying capacity of 168 cubic feet, had only 45 cubic feet of timber in it. It would be seen from this, that the carrying capacity of the standard-gauge truck was just double that of the mètre-gauge truck, and that the cubic quantity of timber in each was very much in a similar proportion, so that there was obviously no saving in dead load.

He would now say a few words upon the running expenses on the narrow gauge, of which no notice had hitherto been taken. In considering these estimates, it was obvious that the greater number of vehicles required to carry a given load on the narrow gauge would require either more powerful and heavier engines, or duplicating the trains. In the first place, he would ask what would happen to the iron girder bridges which General Strachey spoke of reducing to the extent of something like 30 per cent. to 40 per cent. In the latter case it was evident the cost of the extra rolling-stock would have to be taken into account, and also the additional running expenses, which would be greatly increased. Much had lately been said and written, as to the saving in dead load on the narrow-gauge lines. Figures had been freely quoted, showing the proportion of the dead load to the live load, or paying load, on the broad-gauge lines to be in the proportion of 5 to 1, while the proportions on the narrow-gauge lines were shown to be only $1\frac{1}{2}$ to 1. He thought it was now necessary that such loose and unfounded statements should be exploded. He could state, from his own investigation on this subject, on the rolling-stock of the Great Northern railway, that anything like that ratio of dead load to live load did not obtain; while in the case of the light standard-gauge rolling-stock and the light mètre-gauge rolling-stock there was, as he had already shown, nothing to prevent the ratio of the dead load to the paying load being identical in both cases. He believed nothing had more commended these narrow-gauge lines to public favour and consideration than this alleged saving of dead weight, and consequent economy of construction and working. It was easy to gather, from what Lord Lawrence said, that the chief motive which had induced the Government of India to sanction the adoption of the narrow gauge, was the idea of its greater economy in construction and working; and as far as the motive was concerned, it was one deserving of the highest respect and consideration. At the same time, it was, in Mr. Price Williams' opinion, evident that what had been decided on must inevitably result in defeating the very object sought to be obtained. It would also not fail to have been noticed, that Lord Lawrence, while admitting his inability to deal with the engineering data upon which these estimates of saving were based, yet appeared to rely implicitly upon and to believe in the reality of this large saving—which Mr. Price Williams ventured to think had been conclusively shown not to exist. Lord Lawrence, in fact, spoke of the broad gauge as costing £12,000 per mile, and the narrow gauge £7,000 per mile. Those figures representing, it would be remembered, General Strachey's own estimates of the cost of a broad-gauge line with 60-lbs. rails, and a narrow-gauge line with 40-lbs. rails. It was notorious that they had as yet no reliable experience of the actual cost of maintenance and working of these narrow-gauge lines; indeed, sufficient time had not elapsed since their first introduction to allow of any just conclusion being arrived at as to the cost of working them. What little experience they had in regard to the Festiniog line seemed to bear out very strongly the view Mr. Price Williams took, namely, that although there might be a slight saving in the cost of construction of the works of the line, &c., still the narrow gauge must necessarily be more expensive in maintenance and renewals; and he should have been glad if Mr. Spooner had afforded the Meeting some explanation of the very disproportionate cost of the working expenses on that line, to which Mr. Harrison had drawn attention.

It was as well to bear in mind the great difference in the circumstances of light railways in Great Britain and in India. In this country they were intended to serve as branches and feeders to the main lines, and as such, he believed, they were destined to fulfil a very important function, in developing the resources of large agricultural districts at present almost entirely deprived of railway communication. In India, at all events, the majority of the lines that had been constructed or proposed partook really of the character of main or arterial lines, destined to serve large districts with vast populations. Mr. Price Williams would take, for instance, the Punjâb railways, which had the unenviable distinction of being made the battle-field of the gauge question in India. Its mileage from Kurrachee to Lahore alone exceeded the distance from one extremity of the United Kingdom to the other; and from a reference to the valuable statistics he had access to, relating to the population of India, he found that the population of Scinde and the Punjâb, in 1870, amounted to 19,392,346, or very little short of that of England and Wales. Again, he found that the Madras Presidency, through which the projected coast line passed, had a population of 31,312,000—a population equal to that of the whole of the United Kingdom—while the population of Bengal, the North-Western Provinces, and Oudh, served by the railways on the East of India, amounted to about 108,000,000; while that of the Bombay Presidency and the Central Provinces, served by the Great Indian Peninsula railway, amounted to nearly 22,000,000. He therefore thought it was open to grave question whether, quite irrespective of this gauge question, the construction of these lines, on the very light scale proposed, was such as to provide for the future development of the traffic on the Indian railways. He did not now refer to the light character of the permanent way and rolling-stock; these could be replaced, when they had served their purpose, by heavier materials and by heavier stock, as had been the case on the railways in Great Britain and in the United States; but the question was, whether from a desire to realise a doubtful economy on the first cost, a serious restriction would not be placed upon the traffic to be hereafter developed? Whether, in fact, it would not be better and cheaper, in the end, at once to make—on the principal arterial lines at least—the same wise provision for future development of the traffic already made on some of the older lines, which, although at present worked as single lines, had the viaducts and bridges constructed for a double line? He would be glad to know if there was anything in the circumstances of the country or of the people to warrant the assumption that the same law of development would not obtain in India as in this and other countries. It did not require to have spent a lifetime in India in order to know what were the nature and circumstances of the existing railways in India. It was understood that they were not paying. He was disposed to think it was unreasonable to expect they would prove immediately remunerative.

The results he had been able to arrive at, from a careful examination of the valuable statistics relating to the Indian railways prepared by Mr. Juland Danvers, were, he considered, highly encouraging, and already showed remarkable indications of that progressive development to which he had just referred. Mr. Price Williams had prepared the following diagram (Fig. 1) and the tabular statement (page 351) from those sources :—

Fig. 1.

INDIAN RAILWAYS.

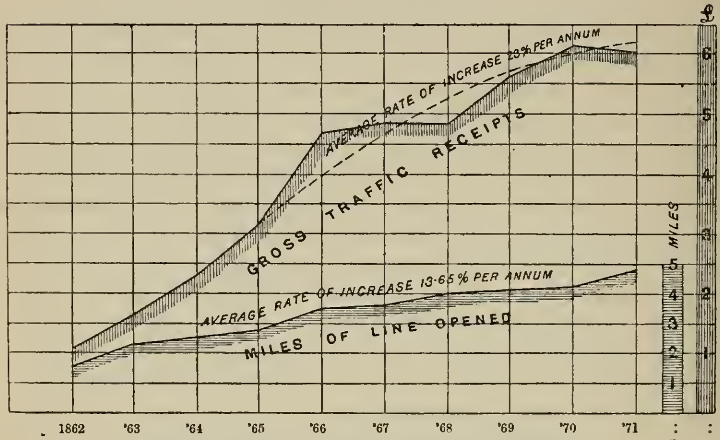

Diagram showing Increase of Traffic, 1862–1871.

Average annual increase of traffic	.. ..	23·00 per cent.	
,, ,,	miles of line..	13·65	,,
,, ,,	traffic per mile	8·23	,,

Without entering into details, he might mention that, in a period of nine years, from 1862 to 1871, the mileage of railways open for traffic in India had increased from 1,584 to 4,778, or on the average a little more than 13½ per cent. per annum; the number of passengers had increased from 7,151,650 to 17,982,892, or on the average 12 per cent. per annum; the passenger receipts from £446,872 to £1,870,142, giving similarly an average of 18½ per cent. per annum; the goods receipts from £609,571 to £4,137,964, or an average of 26⅔ per cent.; while the gross traffic receipts had increased from £1,056,443 to £6,008,106, or an average during that period of 23 per cent. per annum. After making every allowance for the slight falling off in the receipts which had occurred in the last two years, the average growth of traffic on a fixed mileage had exceeded 8 per cent. per annum during those nine years. This rate of increase far exceeded

INDIAN RAILWAYS.—INCREASE per Cent. of MILEAGE opened, PASSENGERS CONVEYED, and RECEIPTS from PASSENGER TRAFFIC, GOODS TRAFFIC, and TOTAL TRAFFIC, from 1862 to 1871.

Year.	Length of Line Opened.	Increase per Cent.	Passengers Conveyed.	Increase per Cent.	Receipts from Passenger Traffic.	Increase per Cent.	Receipts from Goods Traffic.	Increase per Cent.	Total Receipts.	Increase per Cent.
	Miles.	Per Cent.	Number.	Per Cent.	£	Per Cent.	£	Per Cent.	£	Per Cent.
1862	1,584	.. ..	7,151,650	.. ..	446,872	.. ..	609,571	.. ..	1,056,443	.. ..
1863	2,234	+ 41·03	9,202,944	+ 28·68	686,508	+ 53·63	961,532	+ 57·74	1,648,040	+ 56·00
1864	2,581	+ 15·53	11,631,683	+ 26·39	974,370	+ 41·93	1,328,874	+ 38·21	2,303,244	+ 39·76
1865	2,747	+ 6·43	12,826,518	+ 10·27	1,302,432	+ 33·67	1,815,243	+ 36·60	3,117,675	+ 35·36
1866	3,452	+ 25·66	10,120,910	− 21·09	1,278,580	− 1·83	3,328,656	+ 83·39	4,607,236	+ 47·78
1867	3,597	+ 4·20	13,752,591	+ 35·88	1,465,403	+ 14·61	3,386,789	+ 1·75	4,852,192	+ 5·32
1868	3,992	+ 10·98	15,061,677	+ 9·52	1,591,475	+ 8·60	3,239,920	− 4·34	4,831,395	− 0·43
1869	4,023	+ 0·78	16,063,594	+ 6·65	1,742,761	+ 9·51	3,797,558	+ 17·21	5,540,319	+ 14·67
1870	4,182	+ 3·95	17,179,230	+ 6·94	1,847,249	+ 5·99	4,229,713	+ 11·38	6,076,962	+ 9·69
1871	4,778	+ 14·25	17,982,892	+ 4·68	1,870,142	+ 1·24	4,137,964	− 2·17	6,008,106	− 1·13
		+122·81	.. ..	+129·01	.. ..	+169·18	.. ..	+246·28	.. ..	+208·58
		.. ..	.. ..	− 21·09	.. ..	− 1·83	.. ..	− 6·51	.. ..	− 1·56
	9)	+122·81	.. .. 9)	+107·92	.. .. 9)	+167·35	.. .. 9)	+239·77	.. .. 9)	+207·02
	Average	+ 13·65	.. ..	+ 11·99	.. ..	+ 18·60	.. ..	+ 26·64	.. ..	+ 23·00

$$\text{Normal Increase of Receipts with a constant Mileage} = \frac{23{\cdot}00 - 13{\cdot}65}{1 + \frac{13{\cdot}65}{100}} = 8{\cdot}23 \text{ per cent. per annum.}$$

that which had obtained on the railways of the United Kingdom, where, as would be shown by the following diagram (Fig. 2), and the tabular statement (page 353), the rate of increase on a fixed mileage, in a period of twenty-two years, had not exceeded 2½ per cent. per annum.

Fig. 2.

RAILWAYS OF THE UNITED KINGDOM.

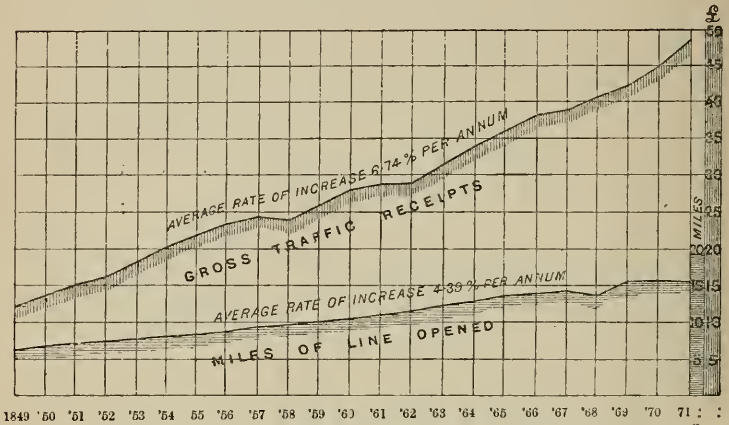

Diagram showing Increase of Traffic, 1849–1871.

Average annual increase of	traffic	6·74 per cent.
" "	miles of line	4·39 "
" "	traffic per mile	2·25 "

STATEMENT showing the INCREASE per Cent. of the GROSS RECEIPTS and MILES of LINE of the RAILWAYS of the UNITED KINGDOM from 1849 to 1871. (Extracted from the Board of Trade Returns.)

Year.	Total Gross Receipts from all sources.	Increase per cent.	Miles of Line.	Increase per cent.
	£	per cent.	miles.	per cent.
1849	11,806,498	..	6,032	..
1850	13,204,669	+ 11·85	6,621	+ 9·76
1851	14,997,459	+ 13·57	6,890	+ 4·06
1852	15,710,554	+ 4·76	7,336	+ 6·47
1853	18,035,879	+ 14·80	7,686	+ 4·77
1854	20,215,724	+ 12·09	8,053	+ 4·78
1855	21,507,599	+ 6·39	8,335	+ 3·50
1856	23,165,493	+ 7·70	8,710	+ 4·50
1857	24,174,611	+ 4·36	9,447	+ 8·46
1858	23,956,751	− 0·90	9,542	+ 1·01
1859	25,743,502	+ 7·46	10,002	+ 4·82
1860	27,766,622	+ 7·86	10,433	+ 4·31
1861	28,565,355	+ 2·87	10,865	+ 4·14
1862	29,128,558	+ 1·98	11,551	+ 6·31
1863	31,156,397	+ 6·96	12,322	+ 6·67
1864	34,015,564	+ 9·18	12,789	+ 3·79
1865	35,890,113	+ 5·51	13,289	+ 3·91
1866	38,164,354	+ 6·34	13,854	+ 4·25
1867	39,479,999	+ 3·45	14,247	+ 2·83
1868	40,912,534	+ 3·63	13,803[1]	− 3·12
1869	42,695,927	+ 4·36	15,145	+ 9·72
1870	45,078,143	+ 5·58	15,537	+ 2·59
1871	48,892,780	+ 8·46	15,376[1]	− 1·04
		+149·16		+100·65
		− 0·90		− 4·16
	22)	+148·26	22)	+ 96·49
	Average	+ 6·74	Average	+ 4·39

Normal increase of Receipts with a constant mileage . . . . $= \dfrac{6 \cdot 74 - 4 \cdot 39}{1 + \frac{4 \cdot 39}{100}} = 2 \cdot 25$ per cent. per annum.

He ventured to think that the fact, that the Indian railway traffic was actually growing at a rate which would double itself in every ten years was most significant, and that it had a most important bearing upon the question now under discussion.

Indeed, it was impossible not to see that, with the large resources in coal and other products, and with its enormous population of nearly 200,000,000, a rapid development of traffic and industrial energy must necessarily follow the introduction of railways in the

[1] These apparent decreases in the mileage are owing to certain alterations in the methods of making the Returns to the Board of Trade.—R. P. W.

large and populous districts in India at present wholly deprived of the facilities afforded by railway communication.

Looking to all these circumstances, there could be no doubt, he contended, that these narrow-gauge lines would be incapable of meeting the demands that would be made upon them by the future development of the traffic of the country.

After what had been so forcibly urged against the break of gauge by Mr. Allport, it was scarcely necessary for Mr. Price Williams to refer to it; but having been connected for the greater part of his life with the particular district which had suffered so much from the effects of this break of gauge, he ventured to say that it was impossible to exaggerate the evils attending it, and that to estimate the money value of the cost, or loss, resulting from a break of gauge at anything like the figure quoted by the Author was simply absurd.

Mr. Price Williams might mention that it was owing to this unfortunate break of gauge that the large resources in good house coal, which the South Wales coal-field possessed, had hitherto been excluded from the London market. The South Wales coal-field, as was well known, was nearly twenty miles nearer London than the Yorkshire coal-field. He might add, that since the Great Western Railway Company had completed the alteration of their line, from London to South Wales, to the standard gauge, a great impetus had been given to the house coal trade in that district, and there was now every prospect of the Welsh coal finding its way into the London market.

The Author, in bringing this important question before the Institution, had fairly challenged the opinions that had been expressed upon it. As a Member of that Institution in no way connected with Indian railways, either professionally or otherwise, Mr. Price Williams had ventured to express his firm conviction, founded upon the results of a long practical experience in this particular part of the subject, that so far as the estimated saving in the permanent way was concerned, it was entirely fallacious. General Strachey had seen fit to remind them that the opinions of the members of this Institution formed but one element in this important question: what the other element was, it was unnecessary for him to inquire. He felt assured, however, that the weighty arguments that had been urged against the adoption of these narrow-gauge lines in India would have their full weight with the Government of India, and that when they had the Paper, with the discussion upon it, before them, they would not fail to recognise the force of Mr. Hawkshaw's suggestion—not to proceed further with their programme of constructing these 10,000 miles of narrow-gauge lines until they had made some more thorough and efficient inquiry as to the soundness of the data upon which these large estimated savings rested.

Mr. A. M. Rendel read the following remarks. Although he was in no way responsible for the Paper which formed the subject of this debate, and, indeed, was not aware that it was in contemplation until it had reached the Institution, still, as entirely sympathising with its Author, and, in common with other members, having been called upon to make observations upon the policy it supported, he did not hesitate to give his views.

He wished, in the first place, to set the Committee of 1870, of which he was a member, right with the Institution in regard to the charge which Mr. Bidder brought against it of being 'packed.' Mr. Bidder appeared to suppose that the committee was appointed by the Government to give an opinion in favour of a conclusion which the Government had already arrived at, and that, for that purpose, the persons placed upon it were selected either from those who were known to hold certain opinions, or from those upon whose docility the Government could rely. Unless this was Mr. Bidder's supposition, the accusation had no point, and if it were so, then he declared that the charge was groundless. A perusal of the reports of the committee would have shown that the duty intrusted to it was not to consider the general question of whether a narrow gauge should be introduced into India. The Government had long made up their minds that for the future the ruling gauge should not exceed 3 ft. 6 in., and the members of the Committee were so informed in the instructions, and all that they were asked to do was to consider whether a still smaller gauge might not be adopted. Now to put on a committee appointed for such a purpose men who were notoriously of opinion that the gauge should be a great deal more than 3 ft. 6 in. — that is to say, 5 ft. 6 in., and nothing else—would have been simply absurd. Common sense dictated the necessity of appointing the members from amongst those persons who might be expected to support a narrow gauge.

But, narrow as the duties were, the Committee could not agree. Mr. Fowler insisted on a 3 ft. 6 in. gauge and a 45-lbs. rail; the rest of the members—Colonel Strachey, Colonel Dickens, and Mr. Rendel—urged a 2 ft. 9 in. gauge, and a 36-lbs. rail. Now, out of this difference of opinion arose that little trip to Norway to which Mr. Bidder had alluded, and which was planned by

Mr. Fowler in the hope that the actual sight of a line of 3 ft. 6 in. gauge at work would have a certain effect in its favour on the untutored minds of his colleagues. Unfortunately, the inspection had precisely the contrary effect; for they came away more strongly impressed than ever in favour of their own views.

The Norwegian railways of 3 ft. 6 in. gauge were, no doubt, most excellent of their kind—'toys' Mr. Andrew would call them—but there was no doubt that their capacity for traffic was in excess of the traffic ever likely to come upon them.

A high average traffic on a Norwegian narrow-gauge line would be represented by about 100 passengers and 40 tons of goods passing over the whole of each line daily; and Mr. Rendel did not think there was much probability of any great increase on this—at all events at an early date. The speed at which this traffic was run was 14 miles per hour. There was, therefore, nothing in the amount of the traffic nor in the speed at which it was run, nor was there anything in its character, to require a gauge as large as 3 ft. 6 in., or a rail as heavy as 36 lbs. Why, then, did Mr. Pihl, on determining to abandon the 4 ft. 8½ in. gauge, take his stand at 3 ft. 6 in. gauge? Partly, Mr. Rendel ventured to think—saying it with the highest respect for him—because he was wanting in the courage of his opinions, and partly because he put too much faith in a certain firm of locomotive builders who told him they could not build a satisfactory engine on a smaller gauge. Old-established locomotive firms were, in his experience, the most conservative people on the face of the earth, and for his own part, he made a point of never accepting their advice, merely because it was their advice, in any matter out of the line of their ordinary daily practice. The heating surface of the largest Norwegian engines was only 400 square feet; and, though the gradients were bad, the ordinary traffic could hardly utilize as much. He found no difficulty in placing as much as 600 square feet of heating surface on the mètre gauge; he could put nearly as much on a 2 ft. 9 in. gauge; and he was satisfied that the bulk of the railways to be built on the mètre gauge in India would not, as a rule, utilize as much as 300 square feet of heating surface.

Each section of the Committee made its report, and the reports went to India for Lord Mayo's consideration; and very sorry Mr. Rendel was when he heard that Lord Mayo, with his natural conservative dread of extremes, had levelled the 2 ft. 9 in. gauge up to 3 ft. 3⅜ in. That was to 1 mètre.

Mr. Rendel would here remark, that he was somewhat surprised at the misunderstanding which had been exhibited in regard to the reasons for adopting the mètre. The simple reason for doing so was, that at the time the gauge was settled it was the intention of the Government of India to adopt for India the French system of weights and measures. It was only natural, therefore, it being Lord Mayo's intention to adopt something between 3 ft. and 3 ft. 6 in., that he should determine to take the mètre; and all the drawings, he might observe, were drawn to the metrical scale.

Now, what was the case for the narrow-gauge system in India? It was presumptuous on his part to re-state it after Lord Lawrence; but for the sake of repetition he would do so. India was a country containing some 1,500,000 square miles—about 30 times the area of England. It was a populous country, but it was an almost purely agricultural country; and being at once populous and agricultural, it was a poor country. England had about 11,000 miles of railway, besides innumerable well-built roads, and long lengths of canal. India had only 5,000 miles of railway; her roads were few and far between, of a kind which would be laughed at in England—dear to make, dear to maintain, dear to work, and impassable at some seasons—and it had next to no canals. The commerce of the country was confined, in fact, to the neighbourhood of great rivers where water carriage was obtainable, and if the bulk of the country was to be brought within the pale of commerce—within, he might say, the pale of European civilization—it could only be so brought by railways. But the country being so vast and so poor, the lengths to be traversed being so great, and the traffic—as experience showed—being extremely small as compared with the capacity of a railway for traffic, it followed that the railways must be as cheap as possible, and might be, and for the sake of cheapness should be, as small as they could be made. Long railways, and not broad railways, were what were wanted, and breadth was dearly purchased at the expense of length. Any railway whatever would give the country all the necessities and all the comforts of railway locomotion; the luxuries and refinements of a more advanced country like England might be left till the traffic could pay for them. In the meantime, the conditions under which the traffic of the country was conducted were such that the want of such refinements would never be felt. That was the view which guided the report which Colonel Strachey, Colonel Dickens, and Mr. Rendel signed, recommending the 2 ft. 9 in. gauge, and a 36-lbs. rail. They considered that to adopt the larger gauge and the heavier rail recommended by Mr. Fowler would be simply to throw away money without any corresponding advantage. If a second gauge was to be introduced, it was clear that it should be the smallest which could do the work.

Now what was alleged against their view? Why, that before all, and above all, there must be unity of gauge; that there must, under no circumstances, be any departure from the present 5 ft. 6 in. gauge, and that the 5 ft. 6 in. gauge could be retained at a very small extra cost over the narrow guage. No doubt those who had increased the narrow gauge from 2 ft. 9 in. to the mètre, and the rail from 36 lbs. to 40 lbs., had done their best to help this view.

The proposition made by some members of the Institution was, as he understood it, to maintain the 5 ft. 6 in. gauge, but to reduce its rail to somewhere about 40 lbs., and it was alleged that with such a rail, at all events, the rolling-stock could be used, and in emergencies, with care, the locomotive stock of the present broad-gauge lines could be employed.

As to the mechanical part of the matter, he had to observe that, when the London and North Western Railway Company were using 13-ton engines, they were also using 65-lbs. rails, and were laying down 75-lbs. rails, and that a 9½-ton engine on the Liverpool and Manchester line threatened the existence of 35-lbs. rails until it was supplied with 3 pairs of wheels. The evidence given before the Gauge Commission in 1846 would corroborate this statement.

Again, he had to observe that a 42-lbs. rail on a broad-gauge line in India was no new thing. It was tried on the Oudh and Rohilkund, broke down under the wagons of the East Indian railway, and was taken up and replaced by a 60-lbs. rail; he knew that it is alleged that the failure was owing to conical wheels being run on flat rails. He did not believe this was the cause of the failure, and he did not believe that any one here would say it was so.

But, assuming that a 40-lbs. rail could be used, the case contended for was that the rolling-stock of the broad-gauge lines, intended to carry and which would soon carry 10 tons per wagon, was far too big for the traffic of the country which the narrow-gauge lines would traverse; that if a special rolling-stock was built for the light lines, it would be economical for neither broad gauge nor narrow gauge, and that transhipment would be resorted to, even if break of gauge was not admitted.

But Mr. Rendel said much more than this. He said that 40-lbs. rails were not obligatory. If the weight could be reduced on the 5 ft. 6 in. gauge, it could also be reduced on the narrower gauge. The 40-lbs. rail was the maximum, and in his view quite unnecessarily heavy. He hoped to carry railways into such out-of-the-way and now desolate districts that he could use rails of something like half that weight. Indeed 30-lbs. rails had already been supplied for one line, and if iron remained at anything like its present price, he for one should recommend the Government to do so generally very soon, for he was satisfied that they were using too heavy a rail. There was a narrow-gauge line now at work in India, about 150 miles from Calcutta, which had only a 32-lbs. rail. The traffic on this line was as heavy as that of many lines the Government would construct, and it had been open for, he thought, nearly ten years. He maintained, therefore, that, even supposing the 40-lbs. rail could be employed on the broad gauge, it would fall far short of the economy which might be effected by means of the narrow gauge.

He should very much like to know what Mr. Bidder would have said if the Government had proposed a 40-lbs. rail on his 'missing link.' He would undertake to say that, with his usual freedom of speech, he would have told the Government their officers were fools, and knew nothing about their business. And how did Mr. Bruce reconcile his proposal with his actual conduct? That gentleman was the Engineer of a line in the south of India which had no political importance whatever, and very little commercial importance. Up to the date of the Government decision to adopt for the extension of that line the narrow gauge, he was supplying it not only with 68-lbs. rails, but with the most expensive form of permanent way generally he could devise—a 'bowl sleeper' road. Now he came and told the Meeting that a 40-lbs. rail on a small wooden sleeper would have done. If so, why did he not propose it before? Of course Mr. Bruce was too shrewd a man not to see his own inconsistency, so he endeavoured to account for it, and how did he do so? Why, he said that economical propositions were not favourably received by the Government, in support of which he quoted some trumpery case about the level of certain platforms.

It was the custom whenever anything went wrong on the Indian railways for the railway officials to charge it on the Government. For instance, in the course of this debate, Mr. Bidder laid most improperly, Mr. Rendel maintained, the loss consequent on the failure of his Punjâb bridges on the Government. Mr. Bruce did the same thing twice in connection with the Great Southern of India. Now, Mr. Rendel contended, that he had as much or more experience of Indian railways as any Engineer here, and he said that charges of this kind were to be ranked with the attacks sometimes made in this country on officers of the Board of Trade, which he should think had now been heard of for the last time. In his experience he maintained that the fault of the Government officers in the main was at the first a too ready acceptance of the views of the Company's officers, followed possibly in some cases after the failures of the Company's officers by what was a too ready distrust of them, and that if ever the history of the relations of the Government to the Companies came to be written, the officers of the Government need not fear comparison with those of the Companies.

He would now proceed to make some remarks upon the narrow-gauge system as applied to the Scinde and Peshawur lines. He would not go into estimates, because he had already said all he had to say in the report to which his name was attached, and because the time they would take was more than he could afford, except as a matter of professional duty; and because, as he also declined to consider the proposal to lay a 40-lbs. rail on the broad gauge anywhere, but specially on these lines, as a serious proposal, there was no necessity from his point of view for him to do so. If the military question was to decide the nature of the construction of these lines, it was folly to talk of retaining all the features of the broad gauge, except the essential features of the powerful rail; and no one, he supposed, was prepared to maintain that those lines could be built with a 60-lbs. rail or a 68-lbs. rail as cheaply as they could be built with a narrow gauge and a 40-lbs. rail.

It was supposed, he believed, that he was one of those who had urged the adoption of the narrow gauge on the Scinde and Peshawur lines. He had given no grounds for this opinion. In searching through the Report on the comparative cost of these lines on the broad and narrow gauge, signed by Colonel Strachey, Colonel Dickens, and Mr. Rendel, no such expression of opinion on the subject would be found. They were asked to give estimates for each gauge, they were not asked to give opinions as to which should be adopted; and accordingly they gave estimates and did not give opinions; and Mr. Fowler, in expressing an opinion, went, as Mr. Rendel told him at the time, beyond his instructions.

Now, when Mr. Rendel was engaged on that Report, he felt perfectly satisfied that for all commercial purposes any gauge would be sufficient for the Scinde and Peshawur lines, but he did not feel satisfied that there might not be political reasons which might make it desirable to construct them as first-class, heavy-railed, broad-gauge lines. If he had any doubt on the subject at the present moment he should, as a matter of loyalty to his employers, hold his tongue on the subject; but he was convinced by the discussions which had lately taken place that the political question was not one which should govern the construction of these lines, and he was satisfied that the man who followed Lord Lawrence in this matter followed a safe and sure guide.

What was the principle of these particular railways as now laid out? It was this. Mr. Rendel assumed that the lines from Kurrachee to Kotree, and from Mooltan to Lahore, would be altered to the narrow gauge. There would then be a great trunk line resting on what was said to be a first-class harbour in the Indian Ocean, and running through the heart of the country to Peshawur, or further, a length of at least 1,200 miles, and throwing out branches on either side as circumstances might warrant. This would give a length of line ultimately exceeding the length of all the Irish railways, and traversing a district twice or thrice the area of Ireland. And it would be complete in itself. The natural division of the traffic of Upper India, between the Indus and the Gangetic valleys, would certainly be as high as Lahore, where the two gauges would meet, because, although the distance from Lahore to Calcutta would be greater than the distance from Lahore to Kurrachee, yet, owing to the lower rate at which the East Indian railway was and always would be worked, goods would be carried at least as cheaply—he might safely say much more cheaply—from Lahore to Calcutta as from Lahore to Kurrachee, and there was no reason to suppose that freights from Kurrachee would be less than freights from Calcutta; indeed there was every reason to suppose they would be higher.

As to the sufficiency of the mètre gauge, or even of a 2 ft. 9 in. gauge for the Indus valley, this must be considered—the Indus was at least as easily navigable as the Ganges. The East Indian railway, in order to compete with the Ganges, had reduced its rates for grain and seeds, which formed some 60 per cent. of its goods traffic, to little more than $\frac{5}{8}$ths of a penny per ton per mile, and even at that rate the river seemed to beat the railway. The river, in fact, could carry goods at little more than a farthing per ton per mile, taking the distance between the points of transport as the crow flies. How was the Scinde railway, which expended five times as much in mere working expenses, to compete with the Indus? He did not believe that, except in special cases, the Indus Valley railway would ever carry any important percentage of the produce of the Indus valley. It would go, as it did now, by boat, and all that the railway would get would be a little cotton downwards, a few bales of piece goods, a little copper and a few 'notions' upwards; and unless it reduced its present rates, he doubted if it would do as much as that.

The only part of these lines which would have any material traffic on them would be the piece on the Peshawur line between the salt-mines and Lahore, a distance of about 100 miles. Above Peshawur, a few stores, reliefs of troops, a few camel-loads of dried grapes, and the few bales of European goods which penetrated through Afghanistan, would comprise the whole. So little was it expected to be, that it was in contemplation to design some sort of a combined locomotive carriage and wagon to run, as occasion might require, between the Jhelum and Peshawur.

His remarks were drawing out to such a length that he should be glad to leave the subject here, but as the estimates to which his name was attached had been attacked on the three following minor points, he must defend them.

First—he was told by Mr. Harrison that no allowance was made for the maintenance of the third rail which it was proposed should be laid between Kurrachee and Kotree, and between Mooltan and Lahore. Now, the fact was, that it had never been proposed that the third rail should be laid. He, for one, never supposed so foolish a thing would be done. He did not know whether the company could compel the Government to do so, but he hoped it would not be so unwise. The right thing to do would be, of course, to alter the gauge at once. All that the Commission did was to make a supposition to meet, in what they thought its worst form, a certain case put to them, and he maintained that they went quite far enough in providing a sum sufficient to lay a third rail without taking into account the cost of maintaining it. At any rate, he contended that the error was unimportant, because the third rail should never be laid.

Second—Mr. Bidder complained that they had not provided for the cost of absorbing the Scinde rolling-stock into some other broad-gauge system. He said that it would have to be taken up the river in boats, at a cost of £50 per wagon, and then be disposed of at a heavy loss. As to transporting it, Mr. Rendel should have thought there would have been no difficulty in taking it up country on the narrow-gauge line, either on narrow-gauge platform wagons, taking off the wheels, or by placing it on temporary narrow-gauge wheels and axles. As to loss in absorption by other lines, that, at the worst, was a mere matter of account. So far as the Government was concerned, it would be money out of one pocket and into the other, and therefore there was no need to make any provision for it in the estimate.

Third—The Commission was twitted—not by Mr. Bidder, who, Mr. Rendel strongly suspected, knew better, but—by Mr. Lee Smith and by Mr. Andrew, with not having provided for the laying a third rail on the whole of the sidings belonging to the Scinde railway.

What was the case? Why, the Scinde railway, which was only 106 miles long, and had a goods traffic equal, on the average, to about 30 loaded wagons per diem, had no less than 60 miles of sidings. The East Indian, with four times the traffic, had only one-third this proportion of sidings, and had certainly more than it wanted. The fact was, they did not know, until Mr. Lee Smith had told them, that the Scinde had all this siding. Had they known it, instead of providing for a third rail upon it, they should have recommended that some fifty miles of it should be taken up and be turned into a hundred miles of third rail, and have reduced their estimate accordingly. Who was responsible for these sidings? The Government, he supposed, as usual. These sidings represented a sum of at least £300,000; which was just as much wasted as if the money were thrown into the sea. No wonder the Scinde railway—a single line, without a work of any importance from one end to the other—had cost £18,000 per mile. These useless sidings represented £3000 per mile at least.

One word more, as to the policy of the Government in laying the Peshawur line alongside the road. Mr. Lee Smith said this was a mistake. But what were the facts? The Peshawur road was crossed by three great rivers, having a united waterway of nearly three and a half miles, and these rivers were at present unbridged. Now the bridging of such rivers was, of course, a matter of very great expense, aggravated in this case by the difficulty of fixing their course, and the consequent large expenditure required for their abutments.

The Government wanted to bridge these rivers for the road; it wanted to bridge them for the rail; and, as a matter of economy, it wanted to kill both birds with one stone. To do this, the rail must be brought to the road. The same bridges could then be made to answer both purposes, and this was being done. That alone was a sufficient justification for the policy of the Government. It might be, for aught he knew, that the salt traffic might be better provided for on Mr. Lee Smith's plan; but, after all, the salt traffic would be no worse off than it was now. It was not of such importance as to deserve that a large scheme should be altered to suit it. So far as the river was concerned, and in all other respects, it would be much better provided for.

He would now proceed to make some remarks upon Indian traffic, and the effective capacity of Indian railways for traffic, with a view to showing that the narrow gauge would be equal to all probable demands upon it. All those who were acquainted with the expectations formed of Indian traffic when Indian railways were first projected must feel that those expectations had not been realised. Mr. Rendel remembered the time when it used to be said that the East Indian railway would require near Calcutta four lines of railway. It was now doubled to the extent of about one-third its length, and was doubled to a greater extent than was necessary. The London and North Western railway carried last half-year 20,661,096 passengers and 11,509,939 tons of goods. The East Indian railway, a line of very nearly the same length, carried in the first half of 1872, its best half-year, only 3,061,567 passengers and 720,280 tons of goods—barely 15 per cent. of the passengers and $6\frac{1}{2}$ per cent. of the goods carried by the London and North Western; and the East Indian had at least twice the goods traffic of any other Indian line, and twice the passenger traffic of most of them, in proportion to its mileage. If it were not for the fact that Indian passengers and goods were carried enormous distances as compared with traffic on English lines, no one of them would pay its working expenses. How came it that in a country so populous and so fruitful the traffic was so small?

It could not be said that the rates were in fault, certainly not on any of the lines in regard to passengers, for the native passengers, who formed about 98 per cent. of the whole, were carried at less than $\frac{3}{8}d.$ per mile; nor on the East Indian, and some of the other lines, could it be said in regard to goods. The average rate on the East Indian, for the last half-year of which the accounts were rendered, was barely $1\frac{1}{12}d.$ per ton per mile, and at present it must be barely 1*d.* per ton per mile. On the London and North Western he was told, on good authority, that the average for goods would be rather above than under 1*d.* per ton per mile, while the average for passengers must be considerably over 1*d.* per ton per mile.

Nor could it be said it was competition; they lost something, no doubt, by the river competition, but the river was no such competitor to the railway as the Midland and the Great Northern lines were to the London and North Western railway.

The truth was that people were too apt to think that because a country was populous, therefore it must afford a large railway traffic. Numbers alone were insufficient. A people must be rich as well as numerous to give large employment to a railway, and a small rich population would give a larger traffic than a poor large one. The people of India were, it was true, very numerous, but they were very poor. Being very poor, they could not afford to travel much, consequently the passenger traffic was small; being very poor, they could not use imported goods in quantity, therefore there was little for a railway to bring; being numerous, they ate up the bulk of the produce of the soil, therefore there was little for a railway to take away. That, combined with the absence of minerals in any large quantities, was why Indian traffics were so small.

But if the traffic offering itself for transport was vastly less in India than in England, the effective capacity of an Indian railway was vastly larger than the effective capacity of the same railway would be in England. He laid stress on the word "effective." An East Indian passenger train carried as many passengers in one train as the London and North Western did in about four and a half trains, and as much goods in one train as the London and North Western did in about one train and a half. He assumed here that the average rates charged on the London and North Western were as before given. If he took the Bombay and Baroda line, he found a still better result as regarded passengers—a Bombay and Baroda train carrying as many passengers in one train as the London and North Western did in six trains. Using round numbers, of course. And there was no doubt that if the Indian lines were worked as they ought to be, an Indian train would carry at least seven times as many passengers, and nearly twice as heavy a load of goods, as an English train.

The difference was of course due to the absence of the first and second class passengers in any numbers, and also to the absence of competition and of the pressure under which English traffic generally was conducted—evils probably irremediable in England, but which were never likely to arise in India. He had been speaking, of course, of the Indian broad gauge. Taking the effective capacity of a narrow-gauge train with the ordinary narrow-gauge engines at half that of the broad—the number of trains that might be run being, of course, the same on the one as on the other—he was justified in saying that the effective capacity of a mètre gauge in India would be considerably greater than that of a 4 ft. 8½ in. gauge in England, and that therefore it might be safely assumed to be largely in excess of any demands which could be brought upon it. No one, he supposed, would dispute that a suitable rolling-stock might be devised for the mètre gauge. If any one did so, Mr. Rendel advised him to run down to Lancaster, to see the specimens at present waiting there for shipment. The only vehicle about which Mr. Rendel had heard a question was the horse-box. Now the horse-box on the East Indian railway carried 6 horses, 3 abreast, on a carriage 20 ft. long and having a wheel base of 11 ft. The horses were placed with their heads pointing inwards towards a central transverse passage in which the groom was placed. He was told they traveled all the better for seeing each other. A similar arrangement could be made on the narrow gauge for 3 horses, with a compartment for grooms on a length of 18 ft. and a breadth of 6 ft. 6 in. In the cattle van there could be carried 6 of the small horses of the country on a length of 18 ft. Camels and elephants did not travel on the broad gauge, and therefore need not be considered for the narrow.

Lastly, as to break of gauge. What case has been made against it? For a long time they were told to ask Mr. Grierson. At last, Mr. Allport got up, and said that he found it very inconvenient at Gloucester, and that he charged the public twenty miles for it. At least, so Mr. Rendel had understood him. He should think, at that rate, the more breaks there were, the better Mr. Allport would be pleased. Then Captain Galton stated that a friend of his told him, that break of gauge damaged salt to the extent of 1*s.* per ton, which he said, taking the relative value of salt in England and in India, made the loss in India nearly 7*s.* per ton. Did Captain Galton believe this himself; or if he did so, did anybody else? What were the facts? The salt which Captain Galton referred to was rock salt, quarried in a certain district about 120 miles above Lahore. This salt came out, as Mr. Rendel was informed, in blocks, which were placed in bags. The bags were either placed in carts or on the backs of camels, and so were slowly brought down to Lahore. Now that part which went by camels had a break of gauge night and morning, so that, according to Captain Galton, it underwent a deterioration to the amount of, say 1*s.* per mile, or, for the whole journey to Lahore, 120*s.* per ton. The value of the salt at Lahore was, he believed, just about 25*s.* per ton more than at the salt-mines, that being the cost of transporting it 120 miles in the manner he had stated. There was, of course, little or no deterioration at all, even with cart and camel transport, much less would there be any with railway transport, even with a break of gauge; and generally all the classes of goods found on Indian railways were such as did not suffer by transhipment. If they did, they would never reach their destination in a saleable condition at all, for the transhipments which Indian produce, or articles imported into India, underwent between the place of production and the place of consumption were numberless. There was no resemblance whatever between English traffic and Indian traffic, and unity of gauge was a refinement necessary enough in England, no doubt, but totally unimportant to India. The only evil of break of gauge in India would be the expense of transhipment. Retardation was a matter of little moment, and indeed would be rarely increased under the leisurely system in which Indian traffic was conducted.

As to the cost of transhipment, an exact estimate could be arrived at. The East Indian Railway Company contracted for the transfer of goods between carts and the railway wagons at its different stations at 6 rupees per 1,000 maunds, which was equal to about 3½*d.* per ton. There was no reason why transhipment from railway wagon to railway wagon should cost as much. Nay, they knew that in the one instance, where the railway actually had in practice the break of gauge at the junction of the Nulhattie narrow-gauge line with the main line, the contract price for transhipment was 1 pie per maund, or just 3*d.* per ton. Now on the London and North Western railway the average sum paid by a ton of goods for transport was about 4*s.* a ton; 3*d.* on that amount would, of course, be a material item, and therefore break of gauge at that rate, as a mere question of money, would be serious in England. But the average sum paid per ton on the East Indian line, owing to the long distances traveled by goods on that line, was as much as 28*s.* per ton. On the Great Indian Peninsula railway it was as much as 43*s.* per ton, and 3*d.* on 28*s.* or 43*s.* was a trifle; and there was no doubt that the great bulk of the goods subjected to break of gauge would be goods going long distances, and paying, probably, from £2 per ton to £5 per ton for freight. A very large proportion of the goods carried on an English line, referring to the mineral traffic, was worth not more, before freight was added to it, than £1 per ton, even at the present time. Few things went into an Indian wagon worth less than £5 per ton. The cost therefore of transhipment would affect their value to a very small degree. Then as to the quantities transhipped. Taking, first, the Nulhattie line. The average daily goods traffic on that line amounted to about 25 tons; say that the whole was transhipped, what did it amount to? And many lines would, he expected, be made by the Government where no larger a traffic than that on the Nulhattie line could be anticipated; for, small as its traffic was, it appeared to pay 5 per cent. on its actual cost. Or, taking the present Great Southern of India railway. The average goods traffic on that line was less than 100 tons, say 12 wagon-loads per day; and supposing the whole of that to be transhipped, where was the difficulty? After all, the question only came to this—that goods that would reach several stations by road would be concentrated by rail on one station. Why should every one be so anxious for feeder roads, and be so afraid of feeder railways, simply because they would be on a different gauge to the main line? So far as transhipment was concerned, both were under identical circumstances. Mr. Rendel had always thought this fear of a break of gauge in India a mere bugbear, and when, some years ago, the question was raised, how the transfer of traffic between the Great Indian Peninsula railway and the East Indian at Jubbulpore should be managed, and the officers of the East Indian line were, for the most part, in favour of the transhipment of goods as opposed to an interchange of stock, he strongly supported them, although he admitted that this junction was the one place in India where the evils of transhipment of goods might at some time be greater than the evils of an interchange of stock. But certainly, at the present moment, they were not so.

As to the political question, Mr. Rendel contended that it was the business of the Indian Government to decide matters of that sort in the interest of India, not in the interest of England. If England chose to consider Indian questions of this sort here, or to make them 'Imperial' as it was called, let the empire find the money, not wring it out of the Indian peasant.

But the financial and political part of the question was no business of his, else he might ask Mr. Andrew if he did not know that the great difficulty of Indian finance was how to raise a far less sum than this £1,600,000, which the Government was annually losing on Indian railways, and of which he seemed to think so little.

Here Mr. Rendel would conclude, did he not think it necessary to correct a misapprehension in regard to the prospects of Indian railways, to which the diagram, which Mr. Price Williams had given (Fig. 1, page 350), might give rise. That diagram showed the rate at which Indian railways and Indian traffic had progressed between 1861 and 1871, and Mr. Price Williams had drawn across it what he considered to be its curve of increment; the object being to prove that this loss of £1,600,000 a year would rapidly disappear. In the early part of the decade selected by Mr. Price Williams, railways had not penetrated into the country sufficiently deep to induce the goods traffic, coming down in carts from the interior, to finish their journey by rail. But as the decade went on, and railways stretched well into the country, it paid the people to use them. The traffic consequently took a somewhat sudden leap. But since that leap was made, the increase had been very moderate. Indeed, the traffic of 1871 was less than the traffic of 1870, the falling off on the East Indian railway alone being over £300,000. The traffic of 1872 would show, he hoped, a trifling improvement; but that, he heard, was doubtful, and 1873 had opened with a heavy fall. Mr. Rendel feared the hopes of Indian railways lay rather in thrift than in increase of traffic. They did far too much work for the traffic they obtained; and they paid far too much for it; and his conviction was, that they were wasting between them half a million a year at least. Until they could knock this half million off their expenses, they could not afford to try what he believed to be their only hope as regarded revenue—a general reduction of rates.

Colonel Yolland, through the Secretary, and by permission of the President, said he thought there were grave doubts whether it was wise to have originally selected a 5 ft. 6 in. gauge for the railways in India. When that gauge was chosen there had been sufficient evidence of the capability of the 4 ft. 8½ in. gauge to prove, in his opinion, that it would be ample for the main trunk lines in India; and after 5,000 miles or 6,000 miles had been constructed on the 5 ft. 6 in. gauge, there should have been much more potent reasons, than any that he had as yet heard adduced, to justify the abrupt substitution of the 3 ft. 6 in. gauge, or of the mètre gauge.

As compared with the 4 ft. 8½ in. gauge, he believed the difference in the cost of construction on that gauge and on the mètre gauge had been greatly exaggerated. If the traffic was to be conducted at a moderate speed—say not exceeding 25 miles per hour—he believed that very sharp curves might be introduced, and safely worked on the 4 ft. 8½ in. gauge, with rolling-stock specially constructed for passing round such curves; and the same argument held good for the 5 ft. 6 in. gauge, although not quite to the same extent.

If, however, the main trunk lines had been constructed on the 3 ft. 6 in. gauge, or the mètre gauge, to the extent of 5,000 miles or 6,000 miles, and if it had been found out that a 2 ft. gauge would suffice for the wants of the country, and that a saving of a few millions would result from the change, he would still caution the authorities not to make that change as regarded the main trunk lines, as, although the money might be saved, it was quite possible that the country would be lost either to the enemy or to a disaffected population. A handful of Englishmen had already had to bear the brunt of great odds in India; and it was possible that a state of affairs might occur again, when facility of transport from one end of the British possessions in India to the other, might be of the very highest importance.

He did not say that the narrow gauge might not be of great utility, in certain districts in India; but the break of gauge should not occur on main trunk lines; and, as a rule, he should prefer to see light rails made use of on the same gauge, rather than that the additional communication should be obtained by the introduction of another gauge. He believed that a great mistake was made in England on the part of the Government. When the report of the Gauge Commissioners was received, which recommended the broad gauge being confined to certain districts, the Government should have said:—"No; let no more extensions of the broad gauge take place—let us take the necessary measures for at once getting rid of it." He thought that would have been wise policy. In the same manner, he now hoped the Indian Government would be induced to retrace their steps, and to revert to the construction of the trunk lines on the same gauge on which so many miles had already been constructed.

Mr. A. S. Ormsby, through the Secretary, and by permission of the President, stated he considered that notwithstanding the Indian Government had obviously committed itself to an erroneous solution of the important question contained in the Paper, he hoped it would yet reconsider its decision. He was in favour of a gradual and permanent alteration of the Indian gauge to one of 3 ft. 6 in. It was now very generally admitted that a 5 ft. 6 in. gauge was too wide for India. The average load to be drawn, as stated by Mr. Rendel, was from 60 tons to 70 tons per train; but, taking it at even the maximum of 120 tons per train, he submitted there was a decided loss of power in setting a 45-ton engine and heavy rolling-stock to draw even the maximum load demanded by Indian railway traffic. If the annual waste of income, consequent upon the loss of power, were capitalised, it would be found to equal in a very few years any loss that might be occasioned by a change of gauge; while ever afterwards there would be a large annual diminution of working expenses, or increase of income, as the practical result of the change. He would, therefore, say to the Authorities:—"You admit you have committed an error in adopting the 5 ft. 6 in. gauge; do not, then, construct another mile of it; but adopt a 3 ft. 6 in. gauge, and gradually use up your present rolling-stock, and reduce the length of the broad gauge annually. In that way, you will bring the power into economical relations with the weight and the speed, and the earnings into a proper proportion to the interest already guaranteed." He had been employed in the Punjâb for some years, and had traveled from Calcutta to Murree, and from there to Kurrachee, so that his views were the result of Indian experience.

Mr. W. P. Andrew, in explanation, and by permission of the Chairman, said that, having been so pointedly alluded to by Mr. Rendel, it was a matter of common justice that he should be permitted to say a few words. He had never previously heard so many mistakes and so many errors in any essay—for it had not the excuse of being a speech. What was written ought to be accurate. Mr. Rendel had asked him how he would suggest that the Government of India should provide £1,600,000 for the deficit occurring from the railways now in operation. He would say the answer was very easy and distinct. Complete the Indus Valley line; connect the Punjâb line with the Scinde railway; and let the Government do, what they ought to have done years before railways were thought of—make roads. How could railways pay in a vast country, however fertile it might be, if roads were not made to the stations? And if railways in India did not pay as large dividends as those who, like himself, had been connected with them for a quarter of a century, anticipated, it was not the fault of those who constructed the lines in co-operation with the Government, but that the Government had not performed, and was not performing, its duty to India, in not having paid sufficient attention to the construction of common roads. As to the allusions to his friend Mr. Bidder—who he regretted was not present on this occasion to answer those strictures as to the bridges, which he could do so much better than Mr. Andrew could do—he would only say he was quite certain that Mr. Bidder never supposed for one moment that the Government Engineers were to give him any assistance in the construction of railway bridges. It was not in their province to have done so. Mr. Andrew would like to know what military Engineers in India knew about railway bridges? Who ever for a moment imagined that they could give advice on the subject? All he could say was, speaking to the best of his recollection, on two occasions the Government Engineers altered the sites of the bridges in the Punjâb, to the great detriment and expense of the Company; and more than that, as had been alluded to by Mr. Bidder, the Government prevented the company when giving the contract to Messrs. Brassey and Co. from arranging for three years' maintenance, after construction. The result was that, in the first year after the opening of the Delhi line, some of the bridges over the large rivers failed, and the Company was saddled with the expense instead of the contractors. As to the other matters, about the sidings on the Scinde line, and as to the Scinde railway competing with the river Indus, he had never heard anything so extraordinary. The Scinde railway was never meant to compete with the river Indus. The object of it was to cut off the traffic of the delta of the Indus; and he believed, ever since the Scinde line had been opened, the traffic of the Indus had been stopped upon the delta, and the railway had carried the traffic from the top of the delta down to Kurrachee. It was to avoid the delays, the dangers, and the losses of the navigation of the delta. As to comparing the Indus navigation with that of the Ganges, he was surprised. The Ganges navigation was greatly superior to that of the Indus. It was not necessary for him to follow further what had been read by Mr. Rendel. He considered the statements that gentleman had made, however valuable as the results of his personal experience, had been answered in anticipation; but possibly those babes in the profession, Messrs. Harrison, Bidder, and Hawkshaw, would have been instructed had they been present. All he would say was, the break of gauge in the Indus Valley system was a matter of imperial importance. He thought the opinion was unanimous that, whatever gauge might be ultimately adopted in India, no alteration ought to be made in the system of the valley of the Indus. Let the Government, if it so pleased them, introduce the mètre gauge on subsidiary lines, but do not let them introduce a break of gauge on the system he had planned and advocated for so many years, a measure which could not fail to produce disappointment to the Government, and disaster to the interests he represented.

Mr. W. B. Lewis said, that he wished to refer to three points raised during the discussion, and to illustrate what he had to say, by information obtained by the Government of Victoria; but before doing so, he must express a hope that they might yet be informed upon whose advice this important step of the change of gauge in India had been taken? Hitherto it had been supposed that the reports, to which frequent allusion had been made, had something to do with the resolution, but now they were told that those reports were written subsequently to the decision, and that with regard to the Indus Valley and Peshawur lines, three of the Commissioners had purposely abstained from expressing an opinion, while the fourth had reported adversely to the course which had been followed. It appeared to him that the issue was narrowed to the question of estimate, but throughout the document which Mr. Rendel had read, it was assumed that by adopting the narrow gauge there was to be an enormous saving gained. If that element was taken away, all he had urged became of very little value. It was also somewhat strange that reference should be made to traffic as it actually was, and as it had been, and that no reference should be made to the traffic as it was likely to be. In the colony of Victoria the question had been debated very keenly, and had been the subject of more than one Parliamentary inquiry. In the evidence given at the bar of the Upper House by Mr. Higinbotham, M. Inst. C.E., the Engineer-in-Chief of the Government railways, Mr. Lewis found, with respect to 220 miles of line, which the legislature had sanctioned, plans and estimates had been prepared showing the difference of cost between a light railway on the standard gauge of 5 ft. 3 in. with 50-lbs. rails, suitable for the traffic of the district, and capable of carrying the existing rolling-stock, except the engines, and a narrow gauge of 3 ft. 6 in., and the difference did not exceed £77,000. That was at the rate of £350 per mile. Those 220 miles would touch existing railways at three places; and the traffic-manager being asked for an estimate of the cost of transferring traffic at those points, gave £3,900 as the cost. That sum, capitalised at 5 per cent., gave £78,000, which at once swept away the whole of the saving. In addition, it was pointed out that not only the cost of transferring the goods would have to be met, but that there must be special stations where the trains of each gauge could come alongside the same platform; and those were estimated at £6,000 each, or a total of £18,000; and further, that those lines being worked alone, and not being suitable for the rolling-stock on the existing lines, it was necessary to add to the estimate, for rolling-stock, say, one-third. The assumed value of the rolling-stock was £500 per mile; one-third of which would be £166 per mile; but, to make himself safe, the Engineer-in-Chief took only £100 per mile: that was equal to £22,000. The account then stood thus:—

	£
Cost of transferring traffic capitalised . .	78,000
Cost of special stations	18,000
Additional cost of rolling-stock . . .	22,000
Total .	£118,000

Against this there was the saving of £77,000 for the narrow gauge, leaving a balance in favour of the existing gauge of £41,000. Pending the decision of the Government, tenders were called for, based on both gauges for two lengths of about 14 miles each, the rails to be provided by the Government; and it was found the saving in one case was £181 per mile, and in the other £150 per mile. If they substituted the higher of these two figures for the £350 taken in the foregoing calculation, they found the balance in favour of uniformity of gauge was increased from £41,000 to £78,000. That was an example of a not very short length of line where the expenses contingent on a change of gauge doubled the saving to be effected by a reduction of gauge. Those figures were arrived at by fair estimates, and confirmed by actual tenders for the work; and it seemed to him, if they only got a saving of £150 per mile or £180 per mile, then all the arguments of Mr. Rendel and of the Author fell to the ground.

The Author, arguing upon averages, assumed an average saving which, when multiplied by many miles of railway, gave so large a total that, if maintained, it would become very important. The fallacy of this mode of reasoning was pointed out by Captain Tyler. As an illustration of this, Mr. Lewis would refer to information given in Mr. Carl Pihl's valuable report to the Agent-General of Victoria. In that report there was given the cost of all the railways in Norway—broad gauge and narrow gauge. The cheapest railway in Norway cost £2,765 per mile, and was constructed on the 3 ft. 6 in. gauge; while the dearest line cost £6,884 per mile, and was also on the 3 ft. 6 in. gauge. What was there called the broad gauge, or 4 ft. 8½ in. gauge, cost £5,812 per mile. It appeared that in the cost of the narrow-gauge lines of Norway there had been the enormous difference of £4,119 per mile, or more than 150 per cent. In the face of such figures as these it was absurd to look at such a country as India and to talk of an average cost that could be multiplied by ten thousand.

With reference to the challenge which had been made to any one to "question with a show of reason" that if the broad gauge had been adhered to in India, the rails would not have been lighter than 60 lbs. to the yard, and the general characteristics of the lines and stocks would have remained the same, he would mention that in Victoria, when the Government determined to make railways into the sparsely populated districts, their Engineer supplied estimates for them on the standard gauge of 5 ft. 3 in., constructed lightly, and at a very reasonable sum per mile. Now it seemed to him that what a responsible engineer in Victoria did, a responsible engineer in India could be found also to do. In Victoria, as in Great Britain, the advocates of the narrow gauge obtained a great deal of popular sympathy. The Legislative Assembly passed, with a good deal of enthusiasm, a Bill for railways on the 3 ft. 6 in. gauge. When the Bill went to the Upper House it was subjected to careful inquiry at the bar of the House, and the result was, that the question of gauge was referred back to the Government for further information. The Agent-General was requested to procure reports from the most eminent engineers in England, America, and Norway. All the reports could not be procured in time, but those from Captain Tyler, Mr. Carl Pihl, Mr. Harrison, and Mr. Woods were received in time to be taken into consideration, and the result was that the Government decided to make light railways, as recommended by their own Engineer, on the old gauge; and the same Assembly which had voted for the narrow gauge rescinded that vote by a majority of four to one. He could not help thinking, if the question had been as fully ventilated with regard to India as it had been in Victoria, they would have seen a different result, and at all events they would not now be asking upon whose advice this serious and, as he believed, unfortunate step had been taken.

Mr. G. Allan read, from a voluminous manuscript, the following remarks. None of the narrow-gauge lines of India being as yet completed, the Meeting was necessarily without information as to the actual cost of their construction and working; and it was chiefly from the experience of other countries that facts could be obtained on which to form an opinion as to the relative advantages of the broad-gauge systems and of the narrow-gauge systems. He proposed, therefore, very briefly to lay before the Institution some opinions of engineers based upon the actual construction and working of narrow-gauge railways in the United States, and particularly of the representative narrow-gauge line of that country, the Denver and Rio Grande railway, the success of which had been so decided, that its gauge of 3 ft. had not only been accepted as the standard narrow gauge of the United States, but so vast an impetus had it given to railway enterprise in that country, that the number of narrow-gauge roads at present working, constructing, surveyed, and projected, represented a total of about 15,000 miles.

The Denver and Rio Grande railway had Denver, the chief town of the territory of Colorado, for its northern terminus, and traversed in a southerly direction the great rocky or mountain plateau of the continent, running along the valleys of the watercourses for a distance of 850 miles to El Paso, on the southern borders of New Mexico. The two territories of Colorado and New Mexico, through which the line passed, had very varied resources, and were together equal in area to four times the area of England and Wales; and although Colorado had but a very sparse population, New Mexico contained more inhabitants than any state or territory west of Kansas, except California; whilst Mexico, the adjoining country, had a population of nine millions. The line would eventually be extended to the city of Mexico, and would form a great north and south trunk road of 1,850 miles in length between the centres of both countries.

The first section, of 76 miles, from Denver was opened for traffic 15 months ago: 120 miles had been in operation for 8 months, and 158 miles for 4 months. It had been visited by many of the leading railway engineers of the United States, and its capacity for passenger and general business was admitted; whilst its reduced cost for construction and equipment had been to them no less surprising. For purposes of comparison with this narrow-gauge road, the Kansas Pacific line of 4 ft. 8½ in. had been taken, because it was built by the same engineers, and partly by the same contractor, and passed through a similar but somewhat less difficult country. The average cost of the Kansas Pacific for construction and equipment was 24,500 dollars per mile against 16,000 dollars per mile for the narrow gauge, representing a difference of 50 per cent. in favour of the narrow gauge. The rails of the broad-gauge line were 56 lbs. to the yard, and those of the narrow gauge 30 lbs. to the yard; but he should state that the cost of transport for the light rails was so enormous that their price on the spot averaged £18 per ton, their cost in England having been only £7 12*s*. 6*d*.

On this subject of cost, he could not do better than state the conclusions arrived at by the American Convention of Railway Engineers last year at St. Louis. It was composed of about fifty railway Engineers, Mr. E. Wragge, M. Inst. C.E., being one of its vice-presidents. It was at that convention that the gauge of 3 ft. was accepted as the standard for narrow-gauge lines, and compared with the broad gauge, the Convention, through its Committee, felt justified in coming to the following conclusions on the question of cost:—

1st. "That in very rough mountainous countries, where it was not necessary to run fast or time trains, the cost of construction of a 3 ft. gauge road would not be over one-fifth of such roads as the Erie, Pennsylvania Central, and Baltimore and Ohio; and that the capacity of the cheap road could at any time be increased by capital, so as to do all the business for all time to come; thereby saving a large amount in first cost, and interest on the same, which was the strongest possible recommendation for capital to invest in narrow-gauge cheap roads, rather than in the expensive broad gauge."

2nd. "That in the broken, rolling country, where most of our roads are constructed, the saving will be about as 1 to 2, namely, that the narrow gauge will cost about one-half as much as the present broad gauges have cost."

3rd. "That in the slightly undulating prairie, or plain country, the cost of construction of a first-class narrow-gauge passenger road, with the equipment suitable for a large freight as well as passenger business, will not exceed three-fifths of what a broad gauge would cost, with what is now called first-class equipment and road-bed; and that the real comforts and safety of the narrow-gauge are fully equal to those on the three great government broad-gauge roads—the Union Pacific, Kansas Pacific, and the Central Pacific."

Mr. Allan considered that these conclusions deserved great attention, as many of the engineers represented chartered narrow-gauge lines in operation or under construction, and were besides men of great experience in railway engineering.

He would hand in a few additional memoranda in respect to the Denver and Rio Grande railroad, which might be useful for reference.[1] It might be worthy of notice that the covered wagons in use on that line would carry about 11 tons of Indian full-pressed cotton in bales. As regarded the general efficiency of the rolling-stock, the Convention reported as follows:—"The Denver and Rio Grande are doing a general freight and passenger business, and are carrying live stock, wool, lumber, and, in fact, every class of freight; and their officers give it as their unreserved opinion, founded upon actual experience, and which is concurred in by connecting broad-gauge roads, that they gain in every case where the size of the car comes in question, and that in no case is the extra room of the broad-gauge car equal to the loss in dead weight."

He thought that these facts were sufficient to prove the capacity of narrow-gauge wagons to convey live stock, and they formed an equally satisfactory answer to the objection raised by Captain Galton against their complete efficiency for ambulance purposes. The German ambulance wagon of the latest type was $24\frac{1}{2}$ ft. long, 8 ft. 3 in. wide, and 6 ft. 10 in. high, and contained accommodation for 10 men, with 138 cubic feet of capacity to each occupant. The corresponding Denver covered wagon was 22 ft. 1 in. long, 6 ft. wide, and 6 ft. high. It would accommodate 6 men, with a similar cubic capacity to each. Or, in other words, it would accommodate more men than was stated by Captain Galton to have been carried by the German broad-gauge stock throughout the late war.

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[1] *Vide* Appendix IV.

So firm were the promoters of the Rio Grande line in their conviction of the success of their narrow-gauge line, that they undertook it without government, state, or local aid, and they had now the satisfaction of seeing it, even in its present uncompleted state, yielding a dividend of 8 per cent. upon its paid-up capital.

During the last seven years Mr. Allan had acquired an intimate personal knowledge of the requirements and resources of India, having reference not only to the nature of the country, but also to its commercial wants. He could safely affirm that, looking to the experience of the construction and working of narrow-gauge railways, the whole of the traffic carried on the present Indian systems could be, with the utmost facility, conveyed upon the new gauge adopted by the Government of India; and if the present type of construction —unfortunately extended over a distance of 5,000 miles in that country—was so greatly in excess of the demands upon it, how much more extravagant would it be to construct a secondary network of the same type. Those 5,000 miles of broad-gauge railway which had been laid out through the most populous and fertile districts of the country, enjoyed the privilege of conveying, on an average, some 675 tons of freight per mile of line per annum, or $\frac{1}{2}$ ton freight per train mile; whilst, on the diminutive line of 2 ft. gauge, in North Wales, there was a freight traffic carried per annum of 10,000 tons per mile of line. The passenger and goods traffic upon the proposed extensions would be insignificant as compared with that commanded by the existing railways, and he would ask whether, if a line of 2 ft. gauge was capable of carrying in one direction only, as the Festiniog line did, fifteen times the average amount of traffic carried on the Indian lines, the mètre gauge adopted by the Indian Government would not be amply sufficient for all possible requirements? There were but three more points to be considered, and he would dispose of them in a few words. They were the question of speed, of break of gauge, and of fitness for military purposes.

With regard to the question of speed, he need only mention that speeds of 35 miles per hour were frequently attained on the Festiniog, Norwegian, and American narrow-gauge lines. Mr. Carl Pihl considered that 25 miles per hour was a suitable constant speed on a 35-lbs. rail; and that opinion was borne out by Colonel Greenwood, who lately informed Mr. Allan that the trains on the Denver and Rio Grande railway were frequently run at a much higher speed, and in fact that the ordinary running time of the trains over 120 miles, with 17 stoppages, was 8 hours; whilst the Scinde railway, with 7 stoppages, on its 5 ft. 6 in. gauge, took

$8\frac{3}{4}$ hours to travel 105 miles. As to the break of gauge in its commercial aspect, he was confident that the allowance of 4*d.* per ton, made by the Author, would be found ample. The experience of all other narrow-gauge lines was conclusive on that point. He should state, too, that a comparison of the consequences resulting to commerce between two of the main lines in England, had no reference whatever to the railways of a country which had only to carry half a ton per train mile, and with which to this day the native carriers by land and water successfully competed, not only for short, but for long distances. The inconveniences experienced in England had been dwelt upon with little consideration of the very different conditions existing in India. There the evils would, practically, be little felt at present, and if hereafter they should—from the increase of traffic and the multiplication of the points of contact of the two gauges—become serious, he ventured to predict that the broader gauge would succumb, as it had done in England, before its narrower and less costly rival. The fact was that by saddling so poor a country as India with an expensive system of railways, the British Government had terribly checked its progress ; for even Mr. Andrew would not deny that had India possessed the 15,000 miles now to be given her, instead of the 5,000 miles it had taken a quarter of a century to provide her with, her social, and commercial, and national progress would have been greatly increased. Was there then such great reason to exult, with Mr. Andrew, on the blessings conferred upon the natives of India by charging them £18,000 per mile for their railways? Would railways be considered an inestimable boon to this country if they could not hold their own against the old road wagon?

As to the military part of the subject, it was admitted that the Scinde and Peshawur lines had great strategic importance, and that the plan adopted by the Government was, under the circumstances, the best. Having looked the question of cost fairly in the face, it had been decided to alter the present two broad-gauge sections, and thereby to establish an unbroken narrow-gauge system between Peshawur and its natural sea-base at Kurrachee over a distance of 1,092 miles. The distance of Calcutta from Lahore was over 1,500 miles; and they had, very properly, looked upon a break of gauge at Lahore as of the less importance, and more especially as the intervening country between Lahore and Peshawur was desert. Lahore, in an emergency, must of necessity be the great centre and depôt for all arms of the service, stores and munitions of war. A break of gauge, therefore, on the edge of a desert country and at the end of a line 1,500 miles long, could not, for one moment, be set against the greater importance of a policy which had for its object the providing of a great system of railway communications, capable of doing all that could be required of them without being, as with the present system, a terrible burden to the country and a source of financial weakness. Mr. Allan thought it would be admitted, even by the most earnest opponents of the mètre gauge, that in adopting 5 ft. 6 in. as the standard gauge in India, a mistake had been made, and that a narrower and less expensive gauge would have sufficed for the wants of the country. If railway construction were now about to be commenced in India, he did not believe that any person present would advocate the adoption of the 5 ft. 6 in. gauge. But railway construction in India was only in its infancy; the 10,000 miles they were told were to be now proceeded with represented but a fraction of what would be ultimately required; and the Government of India, in recognising the mistake that had been made and resolving that it should not be perpetuated, was acting in the highest interest of the great country over which it ruled.

Mr. J. T. Wood said, that during the discussion much consideration had been given to the question, if, under the conditions of a load of 3½ tons on each wheel, a speed of 15 miles per hour, and a minimum goods traffic of 100,000 tons per annum over the greater portion of a line, there was any real economy in the construction and working of a railway on the mètre gauge, over the construction and working of a railway on the 5 ft. 6 in. gauge. Very few speakers, out of the many competent judges, had expressed a decided opinion of marked advantage in the mètre gauge, under those conditions. He suggested that the attempt to substitute the mètre gauge for the standard gauge, instead of rendering it subsidiary to it, was inconsistent with the spirit of the despatch from the Duke of Argyll of the 26th October, 1870, and was not the way to meet many of the present requirements of India as regarded cheap and remunerative transport.

It was usually considered a matter of course that the railway requirements of the military forces in India were of more importance than the railway requirements of the 240,000,000 persons who constituted the inhabitants of that country. He had no intention to go into the question of how or why England held India, but to confine himself to the provision of military transport, which was to take precedence of, and to be paid for by, the public. It had been stated that the existing carrying capacity of a single line, on the standard gauge, was the power of carrying 1,800 troops, fully equipped, 280 miles in 24 hours for many days together.[1] The capacity of the mètre gauge would, of course, be less in proportion. This capacity, however, was perfectly insignificant compared with that of the English railways, by means of which above 100,000 troops could be concentrated on any point within 24 hours. They had, however, the power of greatly increasing the carrying facilities in India in any particular district where the standard gauge existed, not simply by the power of concentrating existing rolling-stock, but by the power of using the concentrated rolling-stock by means of additional sidings, which, with an ample supply of labour, could always be laid down in a comparatively short time. A break of gauge would take away this power. What was the economical consideration that had induced the Government of India to give it up, for at least some years to come, as regarded the Punjâb lines? A contemplated saving of less than one halfpenny in the pound on the annual military expenditure in India, which exceeded fifteen millions sterling per annum, while 4 per cent. interest on the £530,000, which the Author estimated as the saving on the Punjâb lines, was £21,200.

But if Mr. Wood understood some of the previous speakers aright, it had been suggested that the power of carrying 11,000 troops, fully equipped, 280 miles in one week, would meet all the probable requirements of military emergencies in the Punjâb. If so, that result was within the capacity of an ordinary tramway, not even worked by steam power; and the Government would not be financially justified in making an expensive mètre-gauge military railway to be worked by locomotives, when its maximum requirements could be provided for at a much lower cost. The Wimbledon tramway, which had cost considerably under £1,000 per mile, with four cars only, each pair of cars being drawn by one horse, had carried 2,538 passengers about 1,200 yards in one day.

The despatch from the Duke of Argyll, which Mr. Wood had previously referred to, alluded to "lines mainly valuable for strategic purposes," and to "the great military lines of India being now complete." But if provision for military emergencies was to be omitted, and the ordinary military transport only to be considered, let them apply the Author's test of the use of those lines to the military, namely, the use actually made of them by the military. Statistics taken from the printed reports for the half-

[1] *Vide* Parliamentary Paper, 4th April, 1871, p. 39. "Report by Colonel Strachey, Colonel Dickens, and Mr. Rendel, 27th September, 1870."

year ending June last showed the conveyance of the military was as follows:—Scinde, under 6 per cent. of gross receipts; East Indian, Great India Peninsula, Madras, under 4 per cent. of gross receipts; Bombay and Baroda, under 2 per cent. of gross reccceipts; and Eastern Bengal, under 1 per cent. of gross receipts. So that the ordinary military traffic did not amount to one twenty-fifth part of the general traffic of the country.

It was stated in the Paper that the transport of the utmost amount of traffic to be expected on any of the contemplated lines would certainly not be beyond the capacity of the mètre gauge; and that, on the contrary, that capacity would probably suffice for the traffic of the existing 5 ft. 6 in. gauge. Now what were the conditions which had to be provided for, and which were considered by Government essential to the maximum of success? 1, a charge of $\frac{1}{4}d.$ per mile for passengers; 2, a charge of $\frac{1}{2}d.$ per ton per mile for goods; 3, an uniformity of gauge for the subsidiary lines; and 4, a net return, on the average, on the outlay of not less than 4 per cent.

Clearly the arrangements to be made must depend on the amount of the traffic estimated in each particular case; and speed might be considered as only required for exceptional cases, and therefore be disregarded. The estimated traffic might not be sufficient to financially justify the making of any kind of road. They might have to begin with a tramway adapted to a load not exceeding half a ton per wheel, and to be worked by manual labour until the traffic justified the use of animal draught or steam power, and ultimately the conversion of the tramway into a 5 ft. 6 in.-gauge railway; but if they began by a locomotive railway in the first instance, when the estimated traffic would not justify it, they would inevitably impose an unnecessary burden on the tax-payers. It was essential that the cars and wagons on the mètre-gauge tramways should be so constructed and be made of such dimensions that several of them could be conveniently rolled into, and carried on, an ordinary wagon of the 5 ft. 6 in. gauge. This would go far to remedy the evils of the break of gauge as regarded economy in the supply of rolling-stock—by enabling an interchange of stock between different tramways to be made—and as regarded the transport of goods liable to damage by handling. The dimensions of the rolling-stock proposed, as given in Mr. Guildford Molesworth's report, were such, that only a single wagon could be placed on a standard-gauge wagon, and some of the stock, when so placed, would make the load too high for the standard dimensions of the Indian railways.

As regarded the capacity of the mètre gauge sufficing for the traffic of the existing 5 ft. 6 in. gauge, Mr. Wood had doubts as to the cotton traffic being carried on the mètre-gauge lines as economically as on the 5 ft. 6 in.-gauge lines. But he had no doubt that the mètre guage was not economically adapted to the traffic of the district he was more particularly interested in—the district of Eastern Bengal. He would state that, on the Eastern Bengal railway, they had the evils of break of gauge and keen water-competition to contend with. There was a break of gauge between the railway and the warehouses in the city, at one end of the line, and another break between the rail and the boats on the rivers, at the other end of the line. These breaks alone deprived the railway of an enormous amount of traffic. To obviate one break of gauge they had gone to a very heavy expense in bridging a river, and had not yet got the cost of crossing it down to the Author's 4*d.* per ton. The actual cost of transfer of goods between the railway wagon and a vessel alongside might work out at less than 4*d.* per ton, but the delay in the transfer of 1,000 tons was 2½ days, and the traders had found it economical to use sacks for grain and seeds, for the use of which they paid ¾*d.* per sack per trip. There were three kinds of traffic which they could not carry on a mètre-gauge line without having greatly to increase—probably to double—the number of trains, namely, jute, passengers, and fresh provisions. The distance was 152 miles. The goods trains were 11 hours, the passenger and provision trains 7¾ hours on the journey. Jute measured about 10 lbs. to the cubic foot; it was carried either in wooden wagons of 1,008 feet capacity, 18 ft. × 8 ft × 7 ft., or in iron wagons of 1,700 feet capacity. They carried last year 80,000 tons of jute during the 6 months of the season, almost the whole over 152 miles, but 250,000 cubic feet in a day was only a fair day's work. It would have required at least 400 trains more to have carried the same quantity by the mètre gauge, and as the traffic was all one way, they would have had the cost of 800 train miles run over every mile to set off against the interest of any saving that could have been effected by the mètre gauge; which latter, according to the Author's calculation, would not have exceeded £50 per mile. Next, as regarded passengers, they had 1,500,000 per annum to carry an average distance of not less than 35 miles, and they could not afford to go at a slow rate; this would necessitate additional trains for the mètre gauge. There had been instances in which their existing carriages had been blown over in a storm, so that the Canadian or any enlarged carriage on the mètre gauge would not be safe. The fresh provision traffic was considerable, and required in a hot climate much space and peculiar arrangements.

Mr. Wood had alluded to the necessity of adapting the mètre-gauge tramway wagons to being transported by the 5 ft. 6 in.-gauge wagons. He anticipated that might be a solution of the difficulty of collecting and delivering much traffic from terminal stations in the large towns of India and from feeding tramways, and would greatly facilitate the transport by rail, in India, of many articles liable to pillage and injury in transport, such as salt, tea, opium, indigo, grain, and seeds. He laid no stress on the carriage of the dead weight, because he knew, by experience, that the haulage of a full train with a paying load of 300 tons required the consumption of $\frac{14}{65}$ more coal only, than the haulage of the same train empty.

He dissented from that portion of the Paper in which the Author argued that:—"On the reasonable supposition that the rates and fares of the guaranteed railways are fixed with a view to the production of the largest possible revenue, their gross earnings may be regarded as representing what the people of India, for whose benefit the railways were made, are willing to pay for such benefits; in other words, what, in their opinion, these benefits are worth. By being made to pay for the said benefits £1,660,000 over and above the amount represented by the gross earnings, they are plainly paying £1,660,000 more than the persons who use the railways, and who ought to be tolerably good judges of that particular point, do believe the said benefits to be worth."[1] If it was wished to take the test of the user of the lines, let the work done as measured by passenger mileage and ton mileage be taken—the mileage of the soldiers and military and government stores—the mileage of the letters and parcels transmitted by Government, a large portion of the 77,000,000 letters sent through the Indian post-office last year; but they should not take the amount that under a system of average rates and fares, instead of rates and fares applicable to each particular case, had been charged for railway transport in India. A railway in India, as regarded construction and working, cost as much or more than a similar railway in England; but in England they charged a third-class passenger one penny a mile, while in India they charged him only three-eighths of a penny. Near and round London it is now considered good policy, that the rate-payers should be under the obligation

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[1] *Vide* ante, p. 218.

to make and repair the roads for the public good, and they had recently done away with all toll-bars. If they admitted a similar obligation, on the part of the Indian Government, to provide facilities for locomotion, the deficit would represent a payment, by the state, of an amount of 4 per cent. only, of the annual taxation, to obtain the enormous indirect benefit conferred by the railways on the community. No inconsiderable portion of the soreness attending the deficit might, however, be attributable to breaks of gauge of a different character to that of the break between the mètre gauge and the 5 ft. 6 in. gauge. There was the break of gauge between England and India; the break of gauge between the guarantors and the guaranteed; the break of gauge between the different departments of Government; and lastly, the 4*d.* deducted by the English Chancellor of the Exchequer from the income of the shareholders, in pursuance of a narrow-gauge policy, from those who have constructed the railways in India; a sum in itself more than amply sufficient to pay the interest on the assumed extra cost of preserving the uniformity of gauge on the Punjâb lines for 'Imperial' purposes.

Mr. George Berkley said he ventured to make a few remarks on this important subject, chiefly because during the last thirty years he had opportunities of obtaining a somewhat special experience which should have enabled him to form an opinion upon it. Since the year 1849, his attention had been daily directed to the making and working of railways in India, and during that period he had visited India twice, and had traveled over the greater part of the existing lines of railway. Prior to that, in 1843, he had represented his great master, Mr. Robert Stephenson, Past-President Inst. C.E., in altering the gauge of the Eastern Counties railway from a width of 5 ft. 0½ in. to the ordinary 4 ft. 8½ in. gauge; and, subsequently, in attending daily the meetings and experiments of the Gauge Commissioners. Mr. Berkley was also engaged in all the battles of the gauges.

The statement which had been read by Mr. Rendel was chiefly remarkable for its omission of the main element under consideration, namely, the comparative cost of lines of the 5 ft. 6 in. gauge and of the 3 ft. 3 in., or mètre gauge, and on account of the statement that he had expressed no opinion on the introduction of a narrow gauge on the Punjâb railways. The question of uniformity or of non-uniformity of gauge not having been referred to Mr. Rendel, or the other commissioners who reported in 1870, the question naturally was, by whose advice were the narrow gauge and the breaks of gauge introduced? Certainly not by Mr. Molesworth, the Chief Engineer to Government in India, as that gentleman, in 1862, reported against the introduction of the narrow gauge into India, and in his report on the state railways he said that on his arrival in India he was informed, that "its adoption was a question which had been settled, and was not to be re-opened." A probable reason for the introduction of the narrow gauge appeared in General Strachey's statement, that the Government could not disconnect the two separate questions of the suppression of the companies and the change of gauge. Mr. Berkley could not understand what the one had to do with the other. It could scarcely have been imagined that such a reason could have been pleaded, if Mr. Rendel had not stated that "the simple reason for doing so was, that at the time the gauge was settled it was the intention of the Government of India to adopt for India the French system of weights and measures," which reason seemed to Mr. Berkley to be equally inappropriate.

The important feature of the Paper prepared by General Strachey, and which had been read by the Secretary, was the statement that the comparison which guided the Indian Government was that of two things which were not comparable, namely, of two railways, one of which had a capacity vastly superior to, as well as being more complete than the other. It was thus, Mr. Berkley believed, that a great deal of misconception had arisen. Lord Lawrence and Mr. Danvers had both made the same mistake. Lord Lawrence compared existing railways, which cost £12,000 per mile, with estimates for the narrow gauge purporting to cost £7,000 per mile. Every one must know that no such difference between the cost of lines of the two gauges, assuming them to be of equal capacity, could possibly exist. General Strachey and those gentlemen introduced a comparison of cost based on false data, which appeared to have been quite understood by the Author, who did not make a comparison between a railway with rails weighing 75 lbs. per yard to bear a load of 6 tons per wheel, and another line with rails weighing 40 lbs. per yard to bear a load of 3 tons per wheel, but who made the fair comparison between two railways constructed with light rails to carry equally light wheel-loads.

It had been stated by Mr. Rendel that railways of the 5 ft. 6 in. gauge, or even of the mètre gauge, were not justified in India, because, though the country was very populous, the people were very poor. It seemed to Mr. Berkley that Mr. Rendel and the Government had fallen into the error of taking simply the state of things as they actually existed. They had not considered the increase of wealth and of commercial activity caused by the introduction of railways into a country. The idea of the Government on this point, Mr. Berkley ventured to say again, was based upon misconceptions.

It had been alleged by General Strachey that if the state railways had been made on the 5 ft. 6 in. gauge they would have been—not might have been—made with heavy rails. Now the Government having taken the construction of those lines into their own hands, and employing their own officers for the purpose, Mr. Berkley was quite at a loss to conceive why those officers should not make them of the same capacity as the proposed narrow-gauge lines. It had been pointed out to him as a proof that they would not, that when the Government decided to make the line to Hyderabad on the 5 ft. 6 in. gauge they adopted a heavier rail than they were going to adopt for the narrow gauge. Mr. Molesworth, however, had explained this by saying that the Government found there was a large traffic on the Hyderabad line, and they desired that it should be worked by the stock of, and in connection with, the Great Indian Peninsula railway. They also found another railway had a surplus of rails weighing 60 lbs. per yard, and other materials suitable for the purpose, and therefore they laid the line with the heavier rail. Mr. Berkley did not think that such an exceptional case could be taken as a proof that all state railways under state influence, though the gauge was 5 ft. 6 in., would be laid with heavy rails. General Strachey seemed to think they could not send their wagons over light railways, because, he said, they weighed 16 tons, and had only 4 wheels. Now Mr. Berkley was not aware of the existence of any such wagons, but if there should be one or two of that exceptional construction it would be advisable to put another pair of wheels under them. The Author also spoke of the difficulty, in case of emergency, of sending the locomotives of the existing railways over the light rails; therefore, he said, a large stock of surplus locomotives must be kept to meet those emergencies. That was answered by Mr. Bruce, who stated, very properly, that they could use heavier engines at a slower speed. When, however, they knew the speed on the state railways was to be only 15 miles per hour, Mr. Berkley did not hesitate to say they could use locomotives existing in the stock of the guaranteed lines, at that speed, in all cases of emergency.

He did not think that any one would dispute what was stated by Lord Lawrence—first, that they should be guided by past experience; and secondly, that economy—true economy—should be the object of them all. It was especially the engineer's business to accomplish the object desired at the least cost. The Author started upon fair principles, and logically argued the case, but Mr. Berkley ventured to think his data and premises were incorrect. The question which that gentleman had asked was this:—What were the comparative estimates of the cost of construction and working, and the degree of present and future usefulness of lines of equal capacity on the 5 ft. 6 in. gauge and on the mètre gauge, introduced into India under the existing circumstances of railways in India? The Author argued, if Mr. Berkley understood rightly, that the existing lines had not been justified by the traffic that came upon them; that the people of India had been heavily taxed in consequence; that 3 ft. 3 in., or mètre-gauge lines, could be made to do all the work, and that they could be made at a saving of £1,000 per mile; and further, that the evil of break of gauge was represented by an estimate based on the small amount of present traffic at the Lahore station, and hence that it might be valued at a charge of 4*d.* per ton. Mr. Molesworth stated, that some 2,800 miles of state railways were under construction, or were now intended to be made; and Mr. Berkley thought it better to deal with that which was probable, rather than with the mythical 10,000 miles, which represented nothing but a number of round figures which had been ingeniously introduced into the discussion, while the number of breaks of gauge consequent on their construction had not been referred to—the evil which would arise at Lahore being alone mentioned.

With respect to the present railways paying and being justified, he would say, in the first place, that the gross traffic did not represent by any means what the Indian people were willing to pay for the railways. They could not use the railways as much as they desired. He was glad to be supported in his views on this point by Mr. Rendel's statement. There were, in fact, very few bad weather roads; and therefore traffic could not be brought to the railway stations during the monsoon. The stock, establishment and capacity of railways had to be provided, to earn the dividend in some seven months of the year, instead of during twelve months. Roads were indeed much wanted in India for the benefit of the country, as well as for the advantage of the existing railways.

It had already been said that the construction of railways was justified by advantages not represented by dividend. There were certain parts of lines existing which did not and could not have been expected to pay any one, except the Government for strategic purposes; and over the whole of the lines the mails passed free, with the exception of a small charge for the sorting carriages. The officers, soldiers, and the army followers traveled at much reduced fares, resulting in a very large saving to the Government. It would also be generally admitted that the effect of railways, made by Government, could not be argued, as proposed by the Author, simply upon the question of whether the dividend was 3 per cent. or more. When the effect of the introduction of railways into India was under consideration, the increased prosperity of the country, consequent thereon, should be taken into account. Now what had been the effect of railways upon the country already? Taking the year 1849, before the railways were commenced, the imports into the country—representing the comparative condition of the people—were about £8,300,000, and twenty years after that period they were £36,000,000. Taking the exports, representing the productiveness of the country, beginning at £16,000,000 in 1849, they rose to £53,000,000 in 1869. Was that no justification for the construction of the existing railways in India? Again, in the article of cotton the value exported, in 1849, was about £1,775,000, and in 1869, and since that date, the value exported had been upwards of £20,000,000. A number of other products had been much more largely cultivated. The export of jute had risen from about £68,000 to about £2,000,000; timber from £28,000 to £268,000; seeds from £71,000 to £2,000,000 in that twenty years. Did not that show that the growth of the wealth of the country had expanded with the construction of railways, which had given the required facilities for the carriage of the produce to the shipping ports?

In one of his valuable and interesting reports—written in 1860—Mr. Danvers stated that more than 1*d.* per pound was saved by the railways in the carriage of cotton: taking the quantity carried during late years, this saving had been from £2,500,000 per annum to £3,500,000 per annum; and in each of the years 1864-65-66, instead of £1,750,000, as in 1849, £35,750,000 worth of cotton was exported. The quantity, producing this enormous amount, could not have been carried to the shipping ports, if it had not been for the railways, and therefore it would not have been grown; and the difference in the value of that article alone in those three years exceeded 100 millions sterling, or more than the cost of all the railways put together.

The limited dividend now earned did not represent the required capacity of the existing railways. The traffic was bulky; the rates were not high, and the period, during which the dividend was earned, extended over only about two-thirds of the year. Railways must be capable of carrying at least the maximum existing traffic, which had amounted to about £132 per mile per week on a part of the Great Indian Peninsula railway, where the ruling gradient was 1 in 120, and to about £100 per mile per week on an incline of 1 in 40, of 14 miles in length. The power required to work this traffic, on such gradients, was fully as great as that which was necessary to work the traffic of the London end of the London and North Western railway over its gradient of 1 in 330.

It had been requisite to increase the power of the locomotives employed until they were as powerful as any in this country. The traffic which had existed could not be carried on the light 3 ft. $3\frac{3}{8}$ in.-gauge railway proposed by the Government. The traffic had increased, as had been explained by Mr. Price Williams, and it would certainly continue to increase.

The traffic on English railways, between the years 1849 and 1867, had increased in proportion to the increase of capital expenditure in the following ratios:—

Capital expended, 120 per cent.
Passenger traffic receipts, 240 per cent.
Goods traffic receipts, 400 per cent.

It was, therefore, not surprising to find, that the exports from Bombay, which were very largely carried by railway, had increased between 1849 to 1869 from £6,000,000 to £24,000,000.

In the absence of Mr. Fowler, he wished to make an observation on a misapprehension which he thought had arisen respecting that gentleman's report. The Author had based his calculation of cost, partly on figures found in Mr. Fowler's report, and, with the skill of an advocate, he had averaged those with other figures given by Mr. Hawkshaw. Mr. Hawkshaw had given an explanation of his figures, but Mr. Fowler was not there to explain his figures. Mr. Harrison and Mr. Bruce criticised, with fairness and truth, the basis of the estimate in Mr. Fowler's report. Now a careful reading of that report led Mr. Berkley to believe that the Author, as well as Mr. Harrison and Mr. Bruce, had been labouring under a misapprehension. Mr. Fowler stated distinctly, that the "dimensions, quantities, and prices" were assumed by him to be the same as those adopted by the other Commissioners—Messrs. Strachey, Dickens, and Rendel—for the purpose of comparing the cost of a 2 ft. 9 in. gauge, and a 3 ft. 3 in. gauge, the adoption of one, or the other of which, was the practical question referred to the Commissioners; and Mr. Fowler added, to make this clear, "that in carrying out the work I have advised the reconstruction of each detail." He guarded himself by those words from its being assumed that the dimensions, &c., were the bases on which he would calculate the difference of cost between the 5 ft. 6 in. gauge and the narrow gauge.

The subject of cost was all-important in this discussion; for, in the words of the Author, the only reason "for adopting a narrow gauge, was belief in its superior economy." Mr. Berkley had, therefore, taken the trouble, with the permission of Mr. Bruce, to examine that gentleman's estimates; and though he did not exactly agree with Mr. Bruce in the figures he arrived at, Mr. Berkley found that he had adopted a true method of comparison between the cost of lines made on the 5 ft. 6 in. gauge and on the mètre gauge. Mr. Bruce had to construct 216 miles of line on the mètre gauge. Every work was designed, and the quantities were ascertained. He designed them over again, making them sufficient for a line of equal capacity on the 5 ft. 6 in. gauge; the difference of the quantities were valued at the schedule rates of the contract, and he thus arrived at the correct figure representing the difference of cost. Why Mr. Berkley did not quite agree with Mr. Bruce's result was, because he did not think that works designed for a railway generally represented all the works that were required; therefore he thought there might be a percentage of contingencies, larger than was allowed by Mr. Bruce, which would tell upon the difference of the quantities, as well as upon the quantities themselves. Therefore Mr. Berkley preferred to put the extra cost at £250 per mile, instead of £200 per mile which Mr. Bruce had given. To check this further, he had, with the assistance of Mr. Manning—who had been for sixteen years in India, employed on the construction of the Great Indian Peninsula railway—taken out the quantities for upwards of 1,200 miles of the Great Indian Peninsula railway, and had applied to the difference of the quantities of earthwork, ballast, masonry in bridges and culverts, iron bridges, &c., the schedule rates at which such works had been executed, and he thus had arrived at the excess of cost of a 5 ft. 6 in. gauge line over one on the smaller gauge, in the country traversed by the 1,275 miles of the Great Indian Peninsula railway. The sleepers, which formed the most important item of excess, he took at the value per cubic foot at which they were delivered at Bombay, and charged them with 500 miles of railway carriage and 50 miles of land carriage. The result of that calculation was a difference of £400 per mile. Mr. Bruce was having his earthwork done for 4*d.* per yard; the average price on the Great Indian Peninsula railway was 8*d.* per yard, and other prices in Madras were lower than those ruling in the Bombay presidency; but Mr. Berkley desired to err, if at all, on the side of over-estimating the excess of cost of the railways on the 5 ft. 6 in. gauge. He felt sure that the average difference of cost in India would not exceed £400 per mile. This difference of £400 per mile was in excess of that which they would have experienced; but assuming this amount, the account on the Punjâb railways stood thus:—773 miles at £400 = £309,200 = saving by mètre gauge; while the cost of laying the third rail and of extra rolling-stock would be £647,877: showing a balance in favour of the standard gauge of £338,677. To this must be added the cost of the tran-shipping station, the cost of working it, and the cost of maintaining the third rail, where laid. If therefore economy was to be regarded, the cheapest thing to do was to lay the 5 ft. 6 in. gauge, with light rails, on the Punjâb lines.

The saving which would be effected by making railways on the mètre gauge had not been stated by Mr. Rendel, but Mr. Molesworth had given his opinion, "that the saving in first cost of construction, between a narrow gauge line, and one on the standard gauge, was not large." Mr. Berkley had reported on the subject of the gauge of the Indore line, in which the commercial element was combined with the strategic element; which rendered it a case of, at least, as great importance as the railways in the Punjâb. It commenced by a junction with the Great Indian Peninsula railway at Khundwa, about 380 miles from Bombay, and formed part of a through route, from that city and shipping port, to Agra, Delhi, and the north-west of India. By the construction of the proposed state railways, passing Indore, on the mètre gauge, breaks of gauge would be established on that most important line of communication, at Delhi, at Agra, and at Khundwa, as well as at Lahore, and the prosperity of the district would be sacrificed; for while there was excellent iron ore and limestone, which had been worked on the state line, the coal necessary to utilise it was on the Great Indian Peninsula railway; in fact, the break of gauge at Khundwa would separate the coal, the iron, and the limestone districts, as well as important cities, districts, and military stations from their shipping port, and from the metropolis of western India. He believed there could not be any saving of cost equivalent to these serious disadvantages.

He did not propose to discuss, in any detail, the questions of the cost of maintenance and of working. Maintenance, he believed, would be practically the same on both gauges. The sidings on the narrow gauge must, necessarily, be longer, and therefore both their first cost and their maintenance would be greater on the narrow gauge than on the standard gauge. The advantages in point of economy of working would, in his opinion, be on the side of the 5 ft. 6 in. gauge. On this subject he would quote Mr. Molesworth, who, in his report on the State railways, when speaking of the assumed superiority of the narrow gauge—in respect of dead load to load carried—said that it was a fallacy, and also stated—that which every one who knew India would confirm—that the traffic on the Indian railways was bulky, and that for bulky material the broad gauge was the more advantageous.

It had been argued, that a break of gauge in India was very different from a break of gauge in England; but whether in England or in India the evil would be in proportion to the amount of the traffic, and to the character of the traffic passing the point where the break was established. But the comparative inefficiency of the natives at the stations, and the pilfering and bribery going on, made it more serious in India, than in England, and it must be borne in mind, that it would affect the prosperity of the community quite as largely as it would affect the prosperity of the company.

Again, he found Mr. Molesworth had considered this subject, and had reported that the break of gauge was a "very serious evil," the amount of which was more than equivalent to 20 miles of carriage along the line, which he "understood was the estimate of traffic-managers." That was the expression of the Engineer-in-Chief of the State railways of India, with reference to ordinary traffic; but in speaking of the transferring of ordnance and ammunition, he said they, as yet, knew very little about it, and that it was necessary that a series of experiments should be made. Yet, before they had made the experiments—required to prove the efficiency of lines, necessary to ensure the safety of the empire—they were constructing these lines on a gauge the capacity of which was as yet unknown. Without going into details, which he had at hand, with reference to the Great Western railway, he might briefly mention that out of 893 miles of broad gauge—7 ft.—650 miles had been altered to the 4 ft. 8½ in. gauge; and he did not hesitate to prophesy that only a brief period would elapse before all the rest would be altered. It was difficult to arrive at the details of a Railway Company's accounts; but there had been votes taken which gave a pretty good clue to the outlay; and he did not hesitate to say that the cost of the adoption of an uniform gauge on the Great Western railway would amount to fully a million and a half sterling. Notwithstanding that enormous expenditure the company had, partly by getting rid of the evil of break of gauge, risen from a state of great adversity to the position of one of the most prosperous railways of England.

Of course this arose partly from a combination of other circumstances; but the increased prosperity was largely due to the establishment of uniformity of gauge. It had been urged by General Strachey, that the experience as to this English railway would not apply to India. Now was this true? If so, why had the Commissioners calculated on an expenditure of £327,177 on the Punjâb railways, to avoid the evils of break of gauge? and why did Messrs. Strachey, Dickens, and Rendel contemplate that it might be necessary to lay a third rail on the 5,000 miles of existing railway in India at an estimated cost of £5,000,000 sterling?

Mr. Berkley had entered on the consideration of this question with an earnest desire to see whether some compromise could not be introduced; because, though the Government might have made a mistake, they had bought materials for the state railways, and the question naturally arose, could they not use them somewhere? Must they sell them at a loss? If they did as the Eastern Counties Company had done, in days gone by, namely, make a present sacrifice to obtain an uniform gauge, they would, in his opinion, do that which was commercially wise, and which would be for the benefit of the country; but if this was too much to ask, perhaps the material purchased might be utilized on some of the proposed lines? Knowing India moderately well, and considering the fact that they had scarcely any roads to the present stations, that the land required irrigation, and that the harbours in India wanted docks, he ventured to suggest, that the Indian Government had yet a great deal to do, before entering upon the construction of 10,000 miles of railway; and that it would be wise to proceed with those works which would increase the productiveness of the land and utilize the existing railways, and to make only such new lines as would be feeders, or were strategically or commercially necessary, at the present time, in the cheapest way they could, by the adoption of inferior gradients and light rails on the standard gauge.

Colonel J. P. Kennedy, in an authorized communication through the Council, stated that he generally concurred in what had been said in regard to the evil effects of a break of gauge. Still he maintained that if there were no railways in India, and a gauge had to be chosen, the 3 ft. 3 in., or mètre, gauge was not the one which should be adopted. It could be incontrovertibly proved that such a narrow gauge was wholly inapplicable to the peculiar traffic of India. The proper principle was to make the width of the wagon-load proportionate to the width of the gauge. If, as proposed, the load was projected laterally beyond the base, or gauge of the wagon, so as to carry the broad-gauge load on the narrow-gauge line, accidents would inevitably result from such a violation of the ordinary laws of equilibrium. He had carefully classified the goods traffic conveyed over the Bombay, Baroda and Central India railway, 312 miles in extent, during the years 1870 and 1871, according to the approximate specific gravity, per cube foot, compared with the bulk per ton of each kind of goods;[1] and he had arrived at the conclusion that such a classification was the only test by which the fitness of different railway gauges, or the proper distance between the rails of the wagon track for the conveyance of traffic, could possibly be established, as affecting the relation existing between the bulk and weight of the prevalent classes of product to be conveyed in any country. It showed that the fitting gauge for the conveyance of light products must be wide—while that for conveying heavy minerals might be narrow, and that the wide gauge suited both light and heavy traffic. It also proved that the 5 ft. 6 in. gauge, established for India in 1851, was the most suitable that could have been selected; whilst the 3 ft. 3 in. gauge, now sought to be established, would not merely introduce the inconvenience of a break of gauge, as in England, but, in addition, inflict a permanent injury upon the commerce of the country, by providing a wholly unsuitable means of transport for the products to be conveyed.

Mr. J. W. Grover, in an authorized communication through the Council, stated that the entire question of Indian gauge should be reconsidered. It was true that nearly 5,000 miles of railway had been constructed on the 5 ft. 6 in. gauge, but it was stated that 10,000 more miles had yet to be laid down, and if so, he would ask whether it would not be wiser to alter the gauge of the existing lines, rather than to perpetuate an error for the sake of preserving uniformity? At the first view, such a suggestion might appear startling, but he believed a little consideration would show, that changing the gauge was not so formidable an undertaking as persons might suppose. In the course of the last year he had to make several estimates for railways of considerable length and of various gauges, in the Austrian Empire—the lines running over a level country, such as the plains of Hungary. In considering the question of the gauge which should be adopted, he arrived at the conclusion that the saving of a mètre-gauge line, over one of 4 ft. $8\frac{1}{2}$ in. gauge, was from 10 per cent. to 12 per cent., according to circumstances. He believed that amount could be saved in constructing a line on level ground, but

[1] *Vide* Appendix V.

when rough country had to be dealt with, the saving which would arise from adopting the narrow gauge would be much greater. Much depended upon the sharpness of the curves, and the manner in which the line could be made to accommodate itself to the mountain faces. In some places, particularly in the Austrian Alps, he found that he could get a very fair line on the narrow gauge at a moderate cost, with sharp curves, where it would be commercially impracticable to take a 4 ft. 8½ in. gauge line with curves of 10 chains radius. The real question appeared to resolve itself into this:—Was the 5 ft. 6 in. gauge in India made the most of, or was it not to a great extent wasted, and therefore superfluous? Which meant, could not the same-sized vehicles which were now placed upon it, be equally well carried upon a narrower gauge? In Canada, on the Toronto Grey and Bruce railway, vehicles having bodies 8 ft. 6 in. wide, precisely the same width as the Indian vehicles, ran with perfect security upon a gauge of 3 ft. 6 in. At Festiniog, there was a 2 ft. gauge, carrying trains safely round very sharp curves, having a very great super-elevation of the exterior rail. The vehicles had bodies of 5 ft. 6. in. width, and even 6 ft. width, or three times the gauge. In America, the Pullman cars were 11 ft. 3 in. wide on a 4 ft. 8½ in. gauge; and on some English railways, carriages 9 ft. 6 in. wide were used with perfect safety. Hence it was clear that the vehicles might be safely made more than twice the width of the gauge without any great reduction in the size of the wheels. Such being the case, it was manifest that the Indian vehicles should be made at least 11 ft. wide; but if this were done, they would become so bulky and ponderous as to be useless, and would give greater disproportion of dead weight to paying weight than they did at present. Hence, it appeared to him that the Indian gauge was a mistake, and the sooner it was altered the better. To effect such an alteration would, however, require time. Supposing it to be spread over from ten years or fifteen years, the Russians would not very likely be in a position to invade India before the alteration was effected. It was not possible for him, without special data, to give an estimate of the cost of the change, but he could not avoid commenting on Mr. Fowler's estimate of £52,500, or £500 a mile, for the conversion of the 105 miles from Kotree to Kurrachee from 5 ft. 6 in. to 3 ft. 6 in. He had received a letter from Mr. W. G. Owen, M. Inst. C.E., the Engineer of the Great Western railway, dated 27th February, 1873, in which he said, writing of the cost of converting the gauge of an ordinary railway simply laid on cross sleepers:—"I should think about £100 a mile single would be a good allowance, including such small stations as you might have to deal with;" and Mr. F. Fox, M. Inst. C.E.—the Engineer of the Bristol and Exeter railway—also wrote to Mr. Grover, saying that he estimated £100 per mile for the alteration of a single line from the 7 ft. gauge to the 4 ft. 8¼ in. gauge, not including the parts through the stations; the costs of altering the line through the stations he put at £160 per mile. The actual cost of altering one branch line laid on cross sleepers was only £71 per mile; and he summed up by saying that, "at the present prices, £160 to £180 a mile of single line would be a fair estimate for converting a 7 ft. to a 4 ft. 8½ in.-gauge line." The change of rolling-stock was of course a serious difficulty, and that of the engines was still more so; but the Bristol and Exeter Railway Company had been for some time having both engines and rolling-stock so constructed as to be convertible. The Chairman of that railway, in his last Report, observed that "the whole cost of converting the line would be £31,000," or, on 151 miles of double and single line, about £205 per mile. He also stated, that "at that moment they had 300 wagons, convertible at a cost of £3 to £5 each. They had three narrow-gauge engines, and eleven, either convertible or being constructed to be convertible, some of which would cost £50 each to convert, some £250 each; some of the shunting engines, £100 each."

If during the next ten years, or fifteen years, the rolling-stock and engines of the Indian lines were so built as to be convertible, or, indeed, if the broad gauge was transformed into the narrow gauge by degrees, the expense of the alteration might be rendered very small. For the sake of argument, he would assume that the conversion of the Indian single lines, on cross sleepers, would not exceed the cost of that of the double lines of the longitudinal system of the Bristol and Exeter railway, and that if £205 were enough for the latter, it should suffice for the former; always bearing in mind that the change must be spread over a period of years. If it were assumed that Mr. Bruce was correct, and that the saving effected by the adoption of the narrow gauge would be at the rate of £200 per mile only, there would be nearly enough saved out of every new mile of narrow-gauge line built in future to alter one mile of the 5 ft. 6 in. gauge. The Author assumed that 5 miles of 5 ft. 6 in. gauge could be altered for the saving effected by constructing one mile on the narrow gauge. If that estimate was correct, by the time 1,000 miles of new narrow-gauge line were built, the whole of the existing gauge might be altered. Mr. Grover's impression was, that the average saving of the 3 ft. 6 in.-gauge lines over those of the 5 ft. 6 in. gauge would be found to be about £500 per mile for a single line in a country presenting a slight amount of topographical difficulty; and that the general cost of converting the Indian lines from the 5 ft. 6 in. gauge to the 3 ft. 6 in. gauge, spread over from ten years to fifteen years, would be—including allowance for stations, engines, and rolling-stock—from £300 per mile to £352 per mile. But, without acquaintance with India, it was not possible to give an estimate which could be received as universally applicable.

Mr. JOSEPH MITCHELL, in an authorized communication through the Council, stated some facts which had come under his observation, as Engineer to the Dingwall and Skye railway. That line extended from the main through-lines on the Moray Frith, on the east coast of Scotland, to Strome Ferry on the west coast, a distance of 53 miles. The object of the line was to connect the west coast and the islands of the Hebrides, with the east coast. But, as it passed through a thinly-peopled and pastoral district, it was necessary that the works should be constructed with the utmost economy. Mr. Fowler, who was a large landed proprietor in that district, was a Director, and Mr. Mitchell's late partner, Mr. Murdoch Paterson, was instructed to take in offers for a 3 ft. 6 in. gauge. The following data were furnished for his guidance:—"Gauge, 3 ft. 6 in. from centre to centre; rails, 45 lbs. per yard; chairs, none; rails to be fastened by keys, as in Germany and France; ballast, 15 in. deep; excavations, embankments, bridges, &c., to be reduced accordingly; sleepers, 7 ft. by 8 in. and 4 in., half covered, 3 ft. apart from centre to centre. When saving can be made, curves of ten chains radius to be adopted, and gradients of 1 in 50 to be adopted, wherever a saving can be made by the alteration. The weights to be calculated for bridges will be two-thirds per lineal foot of the calculations for the 4 ft. 8½ in. gauge. No dressed stone to be used unless absolutely necessary." A line of 4 ft. 8½ in. gauge was ultimately determined on, and it consisted of sleepers, chairs, and ballast of the ordinary size and strength for that gauge, with works of the most substantial construction, the rails 70 lbs. per yard, the whole capable of sustaining the Highland Company's heaviest engines, with curves, which were very few, of 15 chains radius. As economy was of the greatest consequence, Mr. Paterson drew up the specification and schedules with great care, advertised the works, and received tenders from ten different contractors. The lowest, from a most respectable firm, was—for the 3 ft. 6 in. gauge, £2,860 per mile, and for the 4 ft. 8½ in. gauge, £3,920 per mile, making a difference in cost of £1,060 per mile. The

Directors, after due deliberation, and considering that their goods traffic would be heavy trains of cattle, sheep, wool, and fish, preferred rather to encounter the extra expense of £1,060 per mile, and to adopt the 4 ft. 8½ in. gauge, than to be subjected to the inconvenience and annoyance of a break of gauge at the junction of the main through lines. The line had been completed, including land and every expense, at a trifle over £5,000 per mile, and had been opened for two years. He never heard a complaint or any regret that the 4 ft. 8½ in. gauge had been adopted.

Although a great advocate for the narrow gauge, the Duke of Sutherland, on his extension railway—through his own county to the extreme north at Wick and Thurso—84 miles in length, had felt it prudent to use the 4 ft. 8½ in. gauge, on the ground that it was an extension of the main through line, and that it was objectionable to have a break of gauge.

Colonel J. T. Smith, R.E., F.R.S., in an authorized communication through the Council, stated that the question of the relative amount of the working expenses on the different gauges had apparently been passed over by nearly all the speakers, possibly on account of its obscurity, and of the difficulty of procuring the necessary data for comparison. It appeared to him that the comparative working costs of the two lines were quite as important as their comparative first costs. The necessity of not burthening the Indian revenue had been urged; but it was not the first cost which burthened the revenue, —that would be borrowed in any case—but it was the interest of the first cost, added to the current expenses of working the lines, which was the real charge on the current revenue.

If the cost of the whole programme of the Indian Government were assumed to be £60,000,000, and the interest £3,000,000 per annum, the working expenses, when the lines were developed, might approximately be taken to be equal to the latter sum, and ought not to exceed it; the whole current outlay to be met by receipts being £6,000,000 per annum. But if it were the fact, that the working expenses of the proposed narrow-gauge lines were, by any possibility, double that of the standard-gauge lines, it was clear that the demand upon the current revenue would be exactly the same as if the railways cost £120,000,000, instead of £60,000,000; and in the same way in proportion to any other excess. Hence the working expenses were of fully as much importance as the cost of construction. They were, indeed, more so, if the interests of commerce, as well as those of the Government Treasury, were duly considered.

The difficulty of obtaining data for comparison, as to the working expenses of the several gauges, arose out of the want of a sufficient number of examples of each kind, which would be, in all respects, under equal conditions. There were a number of standard-gauge railways, in Great Britain, which might be safely taken to be well made, maintained, and managed, and under equal conditions, as to the prices of materials and labour, but there were not an equal number of narrow-gauge railways to compare with them. The narrow-gauge lines of foreign countries, even if it were granted that they were equally well constructed and maintained, could not be used for purposes of comparison, nor could the working expenses of tramways, or hastily and cheaply built contractors' lines, be taken as a basis. The only example he was aware of was the Festiniog railway. That line was well constructed and maintained, and had been worked under similar circumstances to other British lines, in respect to the prices of materials and labour. There was ample information regarding it, and it was acknowledged and appealed to as a specimen of the system. He did not propose, however, to argue that the results shown by the Festiniog line, and which would be found unsatisfactory, fairly represented the necessary accompaniments of the narrow-gauge system. He should consider it unfair to erect a general principle upon a single instance, however unexceptionable it might be. All he wished to deduce from the information which that railway supplied was, that there was *primâ facie* evidence to show the probability of there being extra expense in working narrow-gauge lines; and that, considering the equal or even greater importance of that feature of the system, it was of great importance that it should be thoroughly investigated before a decision was arrived at.

Most of the facts connected with the working of the Festiniog line were given in Mr. Spooner's work entitled "Narrow-gauge Railways," published in 1871. First, in regard to fuel, at page 23, it was stated that the consumption up to that time had amounted to "a little over 50 lbs. per train mile, or about double that of an ordinary well-proportioned passenger-engine." Explanations were given to account for that apparent waste; but when all the circumstances of the case were considered, Colonel Smith thought it would be found that no allowance need be made. The consumption of 50 lbs. per train mile was 24 per cent. beyond that of the Madras railway during the first half of 1872, although that line had long and steep gradients. Its cost, also, which was at the rate of 4·96*d.* per train mile, was 59 per cent. beyond the average charge reported on twenty-four of the principal British lines.

In regard to working expenses, there had been an official statement made in March, 1871, by Mr. Guilford L. Molesworth, M. Inst. C.E., now Consulting Engineer for State railways to the Government of India—after a careful analysis of the facts—that the working expenditure per train mile was "nearly double that of the average of English railways, and more than three times as much as that of some Irish railways, on which the rates of labour would probably more nearly resemble those of a remote Welsh district like Festiniog."

Another comparison was afforded in Mr. Spooner's work, page 39, wherein a statement was given of the expenses of working, per train mile, of four English lines and of three Indian lines, as well as of the Festiniog line. The last was stated to be 4·6*s.* per train mile; and the average of the four English lines was 2·773*s.* per train mile; the Festiniog line being thus nearly 66 per cent. in excess. Colonel Smith had made a similar calculation of the working expenses of six leading English lines for the first half-year of 1872, which gave a more unfavourable result. That was the more remarkable, as the Festiniog line was worked under some considerable advantages as compared with others. It was maintained in excellent working order, and the speed was limited to 12 miles per hour. Three-fourths of the gross traffic—namely, that for the downward journey to Port Madoc—was moved by the force of gravity; the remaining fourth, however, being subject to extra haulage, owing to the excess rise in the gradients. The freight was of an exceptionally compact kind, and the trains were completely filled.

Admitting that, on closer investigation, much of the apparent discrepancy between the working expenses of the Festiniog line and of the standard British lines might be accounted for, there nevertheless seemed to be strong presumptive ground for the belief that there was more or less inherent disadvantage in the system. An increase of only one-tenth in the working expenses of the railways constituting the programme of the Government of India would produce an equally onerous burthen upon the finances of the empire as an extra outlay of £6,000,000; which amount was probably more than the saving in first cost which the advocates of the narrow-gauge system would now lay claim to.

Were the discussion confined, as he thought it might be, to a comparison of the employment of vehicles of precisely the same dimensions, namely, those now proposed for the narrow gauge, and almost exactly the same weight, adapted to light rails, set in the one case at 5 ft. 6 in. apart, and in the other at 3 ft. 3⅜ in. apart, the conclusion arrived at would be, a slight saving in the first cost of the narrower line, and an equal or greater saving in the working expenses of the broader line, upon which the same-sized carriages would run more steadily, and there would be room for the employment of more effective and economical engines.

One of the strongest arguments in favour of the narrow-gauge system was, the 'handiness' of the stock and engines, and their suitability for a small traffic, such as was met with on first breaking ground in a new district. But as there was no real difficulty in constructing narrow-gauge stock to run upon rails 5 ft. 6 in. apart, it might perhaps meet the views of the Government of India, under the present circumstances, to lay down and equip the projected lines with light rails, 5 ft. 6 in. apart, and a permanent way able to bear the rolling-stock of the larger lines, together with light vehicles which would be able to traverse all the main lines. When the traffic of the district was so far developed as to require more accommodation, the light rails and vehicles would be pushed forward to form branches, and their place would be taken by rails and vehicles of larger dimensions.

It had been more than once stated, in the course of the discussion, that the existing guaranteed Indian lines had proved to be a commercial failure. He trusted that, before many years had passed, that would be found to be a premature decision. Railways in India had to create trade, as well as to minister to it, and they therefore required a long time for their due development. The lines, to which the statement applied, were only recently finished, and none of them were fully developed; nevertheless, one or two lines had already reached the return which was assumed as constituting success, and they had divided, with the Government, a surplus revenue.

A statement had been made, by one of the highest authorities, that during the last fifteen years an increase had taken place in the Indian revenues, in a great measure attributable to the railways, to the extent of £20,000,000 sterling per annum. If only a moiety of that annual gain was credited to them, it could hardly be considered an unsatisfactory return for the advances out of the Indian treasury, which, up to the present date, were reported to be in the aggregate less than £20,000,000 sterling.

Mr. William Dennis, by permission of the Council, and through the Secretary, stated, that he was constructing a railway in the West of England, on the original broad gauge of 7 ft.; and, having all the quantities and prices of the work in great detail before him, he had gone into a calculation of the saving which would have resulted, had the line been constructed on the narrow gauge of 4 ft. 8½ in.—the difference between these gauges being almost identical with the difference between the mètre gauge and the 5 ft. 6 in. gauge. A summary of the results was given in the tabular statement on page 404.

It gave the comparative cost of a broad gauge (7 ft.) railway, and of a narrow gauge (4 ft. $8\frac{1}{2}$ in.) railway, through a moderately easy country, permitting the use of curves of a minimum of 20 chains radius, both lines being built to sustain an equal rolling load. The quantities and prices were taken from working drawings and contract schedules. The length of the line was 8 miles. The works and way were for a single line.

As affecting the value of the comparison, it would be noticed that the railway was one of only average difficulty; traversing a fairly open country, where nothing would be gained by the employment of curves of less than 20 chains radius. In his calculations he had taken the same weight of rail, the same depth of ballast, and the same scantling of sleepers, reducing the length of the latter from 11 ft. to 9 ft. Under the circumstances, he found the saving which would have resulted from the use of the 4 ft. $8\frac{1}{2}$ in. gauge amounted to £334 per mile, or about $5\frac{1}{2}$ per cent. on the cost of the 7 ft. gauge.

Mr. Edward Woods, by permission of the Council, and through the Secretary, stated that he had no local acquaintance with India; but having been connected with railways, in many parts of the world, for nearly forty years, he was enabled to speak with confidence on the general questions under consideration, more especially as he had had much experience in the construction of railways of various gauges, and of the rolling-stock to correspond. The railways he referred to were of the gauges respectively of 4 ft. $8\frac{1}{2}$ in., 5 ft. 6 in., 3 ft. 9 in., 3 ft. 6 in., 3 ft., and 2 ft. 6 in., besides some tramways of even smaller gauge.

In the commencement of the Paper the following passage occurred:—"Now that, *cœteris paribus*, a narrow-gauge railway must be cheaper than a broad-gauge railway, would, as an abstract proposition, seem to be also a self-evident one. It may indeed be objected, as it has been by a high authority, that the elements which determine the cost of a railway are the size and the weight of the vehicles to be used upon it, and that it is equally possible with the same gauge to use either broad or narrow, heavy or light vehicles; and doubtless it would be possible, by furnishing a narrow-gauge line with heavy rails and other constituents, and with broad vehicles, to cause the cost to exceed that of a broad gauge with light rails and narrow vehicles. Practically, however, the broad gauge is never adopted except when broad, heavy vehicles,

—	Broad Gauge.		Narrow Gauge.		Saving on Narrow Gauge.		Saving per Mile.	Percentage of Saving on Cost of Broad Gauge.	Remarks.
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.			
	cub. yds.	£	cub. yds.	£	cub. yds.	£	£ s.		
Earthwork . .	183,900	8,429	171,730	7,871	12,170	558	69 15	$6\frac{3}{4}$	Formation width. Broad gauge = 15 ft. cut[s]. 17 ft. emb[t]. Narrow " = 13 " " 15 " "
Bridges . . .	No. 9	3,058	No. 9	2,928	..	130	16 5	$4\frac{1}{4}$	8 of these bridges are of masonry. 1 masonry abutments, plate girder top.
Culverts . . .	.. ..	1,411	..	1,333	..	78	9 15	$5\frac{1}{2}$	
Sleepers . . .	No. 16,928	4,444	No. 16,928	3,245	..	1,199	129 14	27	Line and sidings, $9\frac{1}{3}$ miles in length. Broad-gauge sleepers, 11 ft. × 10 in. × 5 in. Narrow-gauge do., 9 ft. × 10 in. × 5 in.
Ballast. . . .	cub. yds. 36,432	3,643	cub. yds. 31,032	3,103	cub. yds. 5,400	540	58 14	$14\frac{3}{4}$	
Land	acres. 60	12,000	acres. $57\frac{3}{4}$	11,550	acres. $2\frac{1}{4}$	450	50 0	$3\frac{3}{4}$	The average price of the land purchased is about £200 per acre. A great portion was given; but for the sake of this comparison it is taken as if it had all been purchased at this rate.
Rails	tons. 1,030	8,755	tons. 1,030	8,755	..	..	..	..	71 lbs. rails (Vignoles), fish-jointed, and bolted to cross sleepers, 3 ft. apart, centre to centre.
Fastenings . .	.. ..	2,324	..	2,324	..	..	..	..	
Laying way . .	lin. yds. 16,192	809	lin. yds. 16,192	809	..	..	..	..	
Fencing . . .	29,040	2,277	29,040	2,277	..	..	..	..	No saving on any of these items.
Level crossings .	.. ..	514	..	514	..	..	..	..	
Drainage of cuttings . . .	.. ..	250	..	250	..	..	..	..	
Electric telegraph	.. ..	224	..	224	..	..	..	..	
Stations . . .	.. ..	5,000	..	5,000	..	..	..	..	
Maintenance and sundries . .	.. ..	862	..	862	..	..	..	..	
Total . .	.. ..	54,000	..	51,045	..	2,955	334 3	$5\frac{1}{2}$	

nor the narrow gauge, except when comparatively narrow and light vehicles, are intended to be used; and in any comparison of the two gauges this intention may always fairly be assumed."[1] Mr. Wood would premise that the preliminary propositions laid down by the Author were substantially without foundation in fact. It had been the duty of Mr. Woods, in certain cases, to construct narrow-gauge lines, which, from the nature of the traffic to be provided for, had necessarily been more costly than broad-gauge lines would have been.

From the observations made by Lord Lawrence, it would be assumed that he entertained the belief in the proposition laid down by the Author, a proposition accepted by all the speakers who had followed on the same side, namely, that the cost of lines might be computed to be in proportion to the width of gauge. Mr. Woods could not but believe that this fallacy had underlain the decision of the Indian Government to adopt the mètre gauge. He also considered that a mistake was originally made, by the Indian Government, in sanctioning the formation of lines equal, and even in some respects superior, in point of construction and equipment, to the first-class English railways. By the establishment of a wider gauge than was necessary, even in England, a very large and unnecessary outlay had been occasioned.

An entirely contrary policy had prevailed in respect to the railways of the United States and of the Spanish Republics of the South American continent. The railways in those countries had, for the most part, been made at much less than half the cost of the Indian lines. They were, nevertheless, well adapted to the requirements of the traffic, and their gauges varied from 4 ft. 8½ in. to 5 ft. 6 in. In the United States and in Peru the prevalent gauge was 4 ft. 8½ in., whilst in Chili and the Argentine Republic the standard gauge had been fixed at 5 ft. 6 in.

In the latter country he had lately constructed a line 247 miles in length of 5 ft. 6 in. gauge, with its sidings, stations, and rolling-stock, for little over £7,000 per mile, with rails of 62 lbs. per yard. Had the advisers of the mètre-gauge lines in India, and those who indulged themselves in the belief that there was necessarily, and intrinsically, an important difference in the cost, as between narrow-gauge lines and broad-gauge lines, taken the trouble to inform themselves of what had been going on, during the last twenty-five years, in other quarters of the world, they would

[1] *Vide* ante, p. 215.

scarcely have lent their sanction to the retrograde policy now commenced.

What had been done in regard to the maintenance of the standard gauge in the colony of Victoria had been fully explained by Mr. W. B. Lewis. Mr. Woods had been enabled to examine the documents and evidence bearing upon the proposed change of gauge in that colony, having been one of the Engineers who were called upon by the Right Hon. Mr. Childers to report on the subject, and he found, after careful investigation of the plans and sections of the proposed line, that the Government Engineers' estimate of the saving to be effected by the adoption of a 3 ft. 6 in. gauge in lieu of a 5 ft. 3 in. gauge, namely, £261 per mile, was in excess, as had been subsequently shown to be the case by the comparative tenders of the several contractors. That such must be the case, under all ordinary circumstances, appeared obvious, when it was considered how large was the proportion of constant and variable expenses; for amongst the former were to be classed the surveys, the preparation of plans and sections and specifications, the preliminary expenses, the compensations to be paid to landowners for severance, and as regarded the works, fencing, retaining walls of embankments, the wing walls of bridges, the fronts of culverts, level crossings, signals, telegraphs, and permanent way; for he held that, given the dimensions of the vehicles, and the weights they were required to carry, those being the elements which should determine the width of gauge and also, indeed, the width of the bridges and the tunnels, the cost of permanent way and ballast would be nearly the same on gauges of 3 ft. 3 in., 4 ft. 8½ in., or 5 ft. 6 in., whilst the variable elements incidental to the difference of gauge consisted of only a small slice of land, another of earthwork, and of culverts and under-bridges corresponding with that difference of width.

The attempt to reduce expenditure by changing the width of gauge in India, and by introducing breaks of gauge, was essentially a retrograde movement; for the object sought could be attained as easily, and with far less inconvenience, by returning to the practice of former years, when lines and rolling-stock in England were of light construction. Mr. Harrison had given the results of his experience on that head. Mr. Woods might also refer to his own experience on the Liverpool and Manchester railway, where during the first ten years of its existence a very large traffic was carried over rails of only 35 lbs. per yard by engines not weighing, on an average, more than 10 tons each. Those weights of rails and of rolling-stock were inferior to what were now proposed for the mètre-gauge lines of India.

The Author had based his justification of the mètre gauge solely on the supposed saving in first cost. He had omitted to take into account the additional cost in working, which such a change would involve; for it was clear that a much larger number of wagons, carriages, and engines would be required to transport a stated amount of traffic, giving rise to a corresponding increase in wear and tear of moving parts, such as wheels, axles, axle-boxes, and springs, and to much additional labour in handling, at the stations, and also the fact that the trains must be more numerous and the train-mileage proportionally increased.

In the course of this discussion it appeared to have been supposed by some of the speakers, that the alteration, by the Great Western Railway Company, of their broad-gauge (7 ft.) lines into narrow-gauge (4 ft. 8½ in.) lines, was to be received as conclusive proof of the superiority of the narrow-gauge over the broad gauge, and hence the inference that advantage would be gained by still further narrowing the gauge; but it was well known that this change had been made solely for the purpose of removing the pressing evils incidental to the breaks of gauge, so fully explained by Mr. Allport. The broad gauge had given way to the narrow gauge, because the extent of narrow-gauge lines was so greatly in excess over that of the broad-gauge lines; and because it would, in most cases, have been physically impossible, by reason of the insufficient widths of tunnels and bridges, to have converted the narrow-gauge lines into broad-gauge lines, even if otherwise desirable.

As regarded the evils incidental to breaks of gauge, he could confirm all that Mr. Allport had said. Since the break of gauge was first established at Gloucester, and afterwards came into play at other points where the two systems met, Mr. Woods had watched its working, and he did not hesitate to express his belief, that the repetition of such a policy, in regard to the arterial lines of India, would retard the development of the resources and the trade of that great empire, and effect an injury so great as to be out of all proportion to the slight saving to be effected, by filling up the connecting links of the great chain of communications between Kurrachee and Peshawur with lines of the mètre gauge.

General Sir Lintorn Simmons, R.E., K.C.B., by permission of the Council, and through the Secretary, said, that having been an Inspector of Railways at the time of the great war of the gauges, he could not conceive how any one could have arrived at the estimate of £1,000 per mile, as the difference of cost between two railways identical as to their powers of conveying traffic and in every other respect, except as to gauge. This, which was the only ground upon which the Author, as the mouth-piece of the Indian Government, had based his argument in favour of a change of gauges, had been entirely disposed of by the statements of Mr. Harrison, Mr. Hawkshaw, and Mr. Bidder. General Simmons believed the estimate of Mr. Fox, that there would be a saving of £200 per mile, was much nearer the truth. General Strachey's argument, that the question was only capable of solution by those who had lived in India, and who were, therefore, conversant with the peculiarities of the country, sounded strangely after a statement of the case for the Government, in which the Author based his calculations on reports and estimates by Mr. Fowler and by Mr. Hawkshaw.

The question was not one of the abstract merits of the two gauges. If there were no railways in India it might be an open question, whether the 5 ft. 6 in. gauge, or any other gauge, should be adopted; but now that 5,000 miles were in operation on the 5 ft. 6 in. gauge, the question was, as the Author had put it, one for the comparison of prime cost, in conjunction with that of the relative expense and inconvenience of working the two gauges.

The cost of construction having been disposed of, there remained the cost of working. On this there could be little doubt that two otherwise identical railways would, as Mr. Fox had stated—as the result of his Canadian experience—be worked without any appreciable difference of expense, either in haulage or maintenance. As to the inconvenience and difficulties occasioned by a break of gauge, they were far more serious than the Author had any idea of. It was not a question of break of gauge merely at one or two points in the Punjâb, but at every point at which the 10,000 miles of railways, the construction of which was contemplated, would come in contact with the 5,000 miles of existing railways. It was impossible to foresee the number or position of the points of junction, but each would involve a break of gauge and a multiplication of the difficulties of which, in the Paper, account was only taken at two or three stations in the Punjâb. The estimate of the inconvenience at these stations was also taken inordinately low. Thus, for instance, the total traffic passing through Lahore in 1870-71 was stated to be 526 tons. The Author said:—" Supposing that, on the completion of the Lahore and Peshawur railway, these quantities will be doubled—becoming a total of 1,052 tons." How did this estimate agree with the experience gained in England, where it was well known that the traffic taken on the best roads, and proved before Committees of both Houses of Parliament in support of railway Bills, had not only been doubled, but had been multiplied a hundredfold? If this were the case in a country like England, abounding with excellent roads, it stood to reason that the ratio of increase must be far greater in a country where previously existing roads were not so good; and it could not be conceived how the Author, or the Indian Government, could accept such a meagre measure of the increase of traffic due to such an improved means of transit. It appeared simply monstrous, that such an estimate should be taken as a liberal measure of the increase of trade, to be brought about by the introduction of railways into a populous country, hitherto devoid, to a great extent, of any good means of communication.

The commercial estimate of the inconvenience of the break of gauge was, however, a small matter compared to the military aspect of the question. As a soldier, General Simmons protested, in the strongest possible way, against the low estimate of inconvenience caused by a break of gauge in, what would become, the great strategic lines of communication throughout India. Here again the Author did not appear to have grasped the importance of the question. It was not merely the delay and difficulties which would be caused by changes at Mooltan and Lahore, which had to be considered, but those which would occur at every station, throughout India, where the two gauges would meet. Much had been said recently of the Central Asian question and of the possibility of Russia attacking our Indian possessions, which the Author instanced as one of the only conceivable contingencies in which the presence of larger masses of troops could be required in the Punjâb, all of which contingencies he said could not fail to cast their shadows before them. Now a more dangerous line of argument could not be conceived. General Simmons was one of those who did not believe that a direct attack from Russia was by any means the greatest danger which could happen to the Government in India; but when attention was directed to the greatest miracle of this present wonderful age, the fact invariably started up that a small island, in Europe, was holding in subjection a population of 200 millions—nearly equal to the whole population of Europe—including some of the most warlike people in the world, by a pigmy force—relatively to the stake at issue—of about 60,000 British soldiers, backed it was true by native troops, but the fact was undeniable that the mainstay of the British power in India was this small and, numerically speaking, insignificant British force. Some persons, who knew India, were of opinion that the natives were so severely punished at the time of the Mutiny, and so thoroughly disarmed, that they were not likely to rise again and to attempt to overthrow the Government. This might be true in the present generation, but this legislation as to railways was for all time, and no man could say, at the pace at which the world was now moving, how long it might be before some of those natives might be ready to move again. It was true they had little or no artillery, and it might be possible to prevent them from acquiring any, but no power could prevent them from acquiring rifles; and in these days of telegraphs, perfected postal arrangements, railways and better education, combinations which were formerly impossible became comparatively easy, and there could be no doubt that rifles in great numbers would more than counterbalance a deficiency in artillery. The native army was now nearly as large as it was formerly, and who could say whether in a few years, as the effect of the putting down of the late Mutiny wore off, that the native army would always remain faithful to the British Government, and would not again rise in mutiny against it? If such contingencies were possible, and the most decided optimist could scarcely gainsay their possibility in a future generation, what was the greatest danger that the present or some future generation might have to encounter in India? The greatest danger to which British power in India was exposed was within our own frontiers; it might be fomented by a foreign power, but, however brought about, it would be within our own territory. What then should be the military policy? To have the troops well in hand, and ready to strike hard at any point which might be threatened with disturbance. Delay would, as in the case of the late Mutiny, add to its violence, and hence the necessity of being able to send forces in any direction, and possibly in more directions than one at the same time, without the least hesitation, to stamp out the sparks of disaffection before they burst into flame.

Suppose for an instant that a rising were to take place in the Punjâb, and that the Sikhs got possession of, or destroyed the rolling-stock of the Punjâb railways, what would be the effect on the movement of British troops into and through the Punjâb, if they had nothing but broad-gauge stock available? or *vice versâ*, if the people south of the Indus got possession of the broad-gauge rolling-stock, what would be the effect upon the movement of troops from the Punjâb upon Delhi? This difficulty would be equally felt all over India, wherever troops might have to be moved, north, south, east, or west, and wherever a junction occurred between the 5,000 miles of existing railway, and the 10,000 miles of contemplated railway. There could not be any doubt that by constructing 10,000 miles of railway on the mètre gauge, to supplement 5,000 miles of already existing lines on the 5 ft. 6 in. gauge, the military force in India would be deprived of half its efficacy.

There was some experience, as a guide in these matters, although it was difficult to estimate its full importance; but recently a million of men had been seen invading a foreign country, and an immense army supported for months, while reducing its capital, in a way which would have been utterly impossible without the aid of railways. The difficulties of those operations were greatly enhanced at times by obstructions in the railways. If the fortress of Toul had been able to hold out, the obstruction to transport caused by a break in the line from Germany to Paris, added to an injured tunnel, would have made the operations before Paris much more difficult, if not impossible, and, in fact, the destruction of a viaduct near Nancy, a few days before the capitulation, produced the greatest inconvenience to the German army. Now an interruption of this nature was very little more serious than a break of gauge; and if the opinion of the German generals could be taken, they would no doubt bear testimony to the enormous advantage they derived from being able to make use of German rolling-stock on the French railways, in addition to the immense quantity of rolling-stock which they captured on the French lines. From the quantity of German railway stock which General Simmons had seen on the French railways during the invasion, he doubted whether it could have been carried out so rapidly and efficiently as it had been if a break of gauge had intervened to prevent the use of the German carriages.

It would be said, and in fact the Author did say, that large bodies of troops would not require to be moved; but the camp followers, who were essential to the existence of an army in India, were well known to be as numerous, or even more so, than the armies themselves, and those camp followers had all to be fed and cared for, as well as the actual combatants. Therefore the arrangements must contemplate large numbers, all of which should be moved and supplied with a regularity of which clockwork was but a type, and, in order to be effective, with the greatest possible speed.

The operations of an army in war time included, in addition to the supplies, the removal of the sick and wounded, whose sufferings a break of gauge might greatly aggravate. The German wounded were taken many hundred miles into the interior of their own country, without being moved from the carriages—expressly fitted in Germany for the purpose—in which they were placed almost on the fields of battle. In India, also, where appliances for the preservation of food did not abound, the power of bringing up live stock to feed the British soldiers, who were accustomed to fresh meat, would be greatly interfered with, wherever a break of gauge intervened; as also the supply of horses, and all stores, whether warlike, clothing, food, or whatever their nature might be.

What then must be thought of estimating the military inconvenience of making 10,000 miles of the mètre gauge in all parts of India, by disposing of it with a remark, that a regiment could be shifted from one train to another in half an hour? a statement which in itself was totally devoid of proof, and was contrary to the experience of every man who had ever seen a regiment equipped for active service.

If a break of gauge had existed on the lines in Germany, the army, instead of taking less than three weeks from the first order for its mobilization, until it had concentrated and struck its first blow on the soil of France, on the 4th August, 1870, followed by two others on the 6th, which might be said to have almost settled the issue of the campaign, would have been crawling along in the interior of Germany, changing from train to train, and assembling behind the fortresses of the Rhine for another fortnight or three weeks, during which the Rhine provinces might have been overrun, and possibly a blow might have been struck at the South German states.

Under such supposed circumstances the trifling saving of expense arising from the mixture of gauges would have been more than a hundredfold repaid by the misery and ruin wrought upon the country. It was spared such a disaster entirely through the concentration of the army, which was only possible with continuous and unbroken lines of railway.

It was objected that the broad-gauge rolling-stock, now existing in India, could not traverse light broad-gauge railways, constructed as the lines on the mètre gauge were to be, with light rails. That was a fallacy as regarded all the stock—except, perhaps, the engines—and even the greater part of those engines might traverse them at slow speeds—but as traffic increased, by the natural law of development, which invariably followed the introduction of improved facilities for transport, the light rails would be replaced by heavier rails, and then the objection would disappear. On the contrary, when the light rails, now proposed to be laid, on the mètre gauge, came to be replaced by heavier rails, where would be the estimated economy of construction? and the interchange of rolling-stock would be impossible.

A break of gauge could no more continue for ever in India than in England. The time would come, therefore, if those 10,000 miles of railway were made on the mètre gauge, when the 5,000 miles of existing lines would have to be altered, the expense of which must be set off against the anticipated saving. This unification of the gauges might be deferred for many years, but what dangers might not occur in the meanwhile; and during all those years the British policy would be cramped and the hold of the country weakened by a policy which, for a paltry saving, would have deliberately deprived the British Government in India of a very large proportion of its power and strength.

Mr. E. W. Young, by permission of the Council, and through the Secretary, stated that he had superintended the construction of a railway of 3 ft. gauge in Nova Scotia, and his experience had much impressed him with the capabilities of narrow-gauge lines. The railway to which he referred was constructed for the Glasgow and Cape Breton Coal and Railway Company. It was about 18 miles in length, exclusive of branches, and had been built to carry coal from several new mines. The rails weighed 50 lbs. per yard, the ruling gradient against the traffic was 1 in 100, and with the traffic 1 in 75. The wagons weighed about 1 ton 18 cwts. each, and the break wagons about 2 tons, carrying 4 tons of coal. These wagons were somewhat heavier than an ordinary freight wagon, in consequence of a peculiar structure, which had been adopted to enable coal to be shipped with rapidity. The Fairlie engines, which were used, would each take a train of 35 cars, weighing about 207 tons, up the gradient of 1 in 100 at 10 miles per hour with a pressure of only 100 lbs. of steam. As they were warranted capable of working up to 140 lbs. of steam, their power must have been still greater, the adhesive power of the engine being not far from 4 tons. The sharpest curves—in or close to stations—were 5 chains radius. He had frequently seen a train of empty wagons—which were more likely to get off the rails than when they were loaded—occupying with the engine nearly a whole quadrant of a circle, pushed up a gradient of 1 in 75 along a curve of 5 chains radius, there being no guard rail, at the rate of about 6 miles per hour. The running of the engine and its train was remarkably smooth; the train, as seen from the engine, when running along a piece of straight line, generally appeared like a rigid structure.

These facts were sufficient to show the great capabilities of a 3 ft. gauge, and would, he thought, prove that lines of the mètre gauge were perfectly capable of carrying all the traffic that they were likely to be called upon to accommodate, in India, for the next few centuries. It was argued by the opponents of the mètre gauge, that light railways on the broad gauge could be made at a cost not much in excess of that of the narrow gauge, and that the estimates, put forward by high authorities, of the saving expected to be realised by the adoption of the mètre gauge were fallacious. In answer, it might be said, that even if the same weight of rail were used in both cases, the saving in first cost was quite enough to make it profitable to adopt the narrow gauge—in spite of the break of gauge, and without reckoning the great advantages of a lighter and handier rolling-stock. But it was not necessary to enter minutely into the matter, to understand that the working expenses and the cost of repairing would be greater on a light broad gauge than on a narrow gauge; for the injury to a light permanent way under traffic of wagons weighing 12 tons each, or thereabouts, when loaded, must be far greater than with double the number of wagons weighing only 6 tons each. Even the engines on the broad gauge, if of the same power as those on the narrow gauge, must be somewhat heavier. As the traffic in India was certain to be light, there must be a constant running of partially-loaded wagons. The greater the capacities of the wagons the more unprofitable dead weight was likely to be carried. On the other hand, to make the capacity of the broad-gauge wagons only equal to that of the narrow-gauge wagons would involve a great waste of material, the wagons would be nearly all 'underframe,' and their weight much greater than that of the properly proportioned wagons of the narrow gauge. In short, it appeared evident that any attempt to rival the narrow gauge, with its permanent way and rolling-stock properly proportioned to one another, by an emasculated broad-gauge system, must be a failure.

The injurious effect of a break of gauge was another objection urged against the proposed introduction of the narrow gauge, and the case of the English Great Western railway was cited. But the cases were entirely different. In the one case the traffic was heavy and the lines short, in the other case the traffic was light and the lines long. The trivial character of this objection would be seen, when it was considered that in America there were many different gauges, and in some cases railways had been made purposely of a gauge different from those with which they were connected. Moreover, it was possible to alter the gauge of the existing lines at a future time; and this was now being done to the extent of thousands of miles in Canada. During the change, a third rail, or intermediate rail, could be laid down, which, however, he thought would be found to be unnecessary.

Another objection insisted upon against the mètre gauge, especially with reference to the Indus Valley line, was, that its carrying capacity was so small, that in the event of a war with Russia it would be impossible to bring up troops and munitions of war with sufficient rapidity, from the coast to the interior. The answer to that objection, and, indeed, to all objections against the carrying capacity of narrow-gauge lines was, that in one sense carrying capacity might be said to be independent of gauge, but dependent upon the amount of rolling-stock at hand. The total horse power of the engines, and the total cubic space of the wagons, represented the carrying power, whether the gauge was broad or narrow. With an unlimited supply of rolling-stock an army and its 'matériel' could be transported with all desirable rapidity.

The main argument in favour of the narrow-gauge system was, that at least the same income could be earned by its means as by the broad gauge, on an amount of capital considerably less than would suffice to build an equal length of broad-gauge line. He agreed with other narrow-gauge advocates in thinking, that the percentage of working expenses on the narrow gauge would be less than on the broad gauge, and therefore that the former would earn the larger income.

It had been stated that the great want of India was a sufficiency of ordinary roads to feed the railways. Now, although he had no personal experience of India, he could easily imagine that the construction and maintenance of roads in a tropical country, with its dense jungles, alluvial plains, monsoons, and rapid growth of vegetation, might be a very expensive matter; and he should not be surprised if it would be found cheaper to construct wooden tramroads—with rails of wood faced with angle iron, or with very light iron rails—on which the wagons of the mètre gauge could be drawn, by bullock power or horse power, to large villages situated a few miles away from the course of the line. By constructing such tramroads, where steam power would not be used, the advantage of having to provide for the transport of wagons weighing only 6 tons instead of 12 tons was very apparent.

Looking at the facts that India was not a manufacturing country, that its population was poor, its climate enervating, its beasts of burden diminutive, its labouring classes physically weak, and the loads they were accustomed to handle small, he could not help thinking, that if there was any country in the world to which the narrow-gauge system, with its light and handy rolling-stock, was suited, that country was India.

Mr. G. G. Heppel, by permission of the Council, and through the Secretary, said it had come to his knowledge that in the statement read by Mr. Rendel, the following remarks occurred:—"A 42-lbs. rail on a broad-gauge line in India was no new thing. It was tried on the Oudh and Rohilkund, broke down under the wagons of the East Indian railway, and was taken up, and replaced by a 60-lbs. rail; he knew that it was alleged that the failure was owing to conical wheels being run on flat rails. He did not believe this was the cause of the failure, and he did not believe that any one here would say it was so."[1]

Now, as that statement was put forward by Mr. Rendel as an argument against adopting light broad-gauge lines in India, and as it was not strictly correct, Mr. Heppel would give the exact state of the case.

Firstly, then, as regarded the weight of the rail. The rail used on the Lucknow and Cawnpore branch of the Oudh and Rohilkund railway—42 miles in length—was 36·37 lbs. per yard; nothing between that and the 60-lbs. rail adopted for the whole system of the Oudh and Rohilkund had ever been used on that line. It was of a very weak section as regarded the head, having been designed with a view to obtaining extra strong joints, so that the rail might be of uniform strength throughout.

Secondly, Mr. Rendel did not believe that the failure was due to the running of conical wheels over a flat rail. There was certainly nothing incorrect in the statement, but as he presumed that Mr. Rendel also expected other people to be of the same opinion, Mr. Heppel would here state that the cause of failure of this rail was due to the fact, that the Company, not having sufficient rolling-stock of their own, borrowed the heavy stock of the East Indian Railway Company, which, of course, had conical wheels, and ran it over their rails, which were laid flat; this caused the rails to laminate, and in some cases the heads were bent down. Added to this, the rails were laid on light corrugated iron sleepers, which had no hold whatever on the ballast, and they were fastened to them only at the centre of each sleeper. The tendency of the sleeper, therefore, was to stretch out into a flat plate. The sleepers were $\frac{1}{8}$ in. thick.

He did not, therefore, think that the failure of a line constructed with a very defective section of light rail—36 lbs. per yard—laid flat,

[1] *Vide* ante, p. 358.

on corrugated iron sleepers, to which it was imperfectly fastened, and run over by heavy wagons with conical wheels, could be taken as a conclusive proof that light broad-gauge lines could not be satisfactorily constructed and maintained.

He made these remarks, as the statement made by Mr. Rendel would induce prejudice against a system of light broad-gauge lines; which, considering the mileage now open in India on a broad gauge, was, as he believed, the only practical way of obtaining economy in the working and maintaining of new railways. He would suggest a rail of from 42 lbs. per yard to 45 lbs. per yard, on wrought-iron sleepers, or, if possible, on longitudinal timber sleepers.

Mr. J. Grierson, in a communication authorized by the Council, and through the Secretary, stated that as the case of the Great Western railway had been frequently referred to, it was desirable to notice that, within a recent period, that railway—exclusive of broad-gauge lines towards Plymouth, Penzance, &c., in which the Great Western Railway Company was interested with other companies, and irrespective of narrow-gauge lines, north of Hereford and Wolverhampton, which it owned jointly with other companies—consisted of 770 miles of broad gauge, 175 miles of mixed gauge, and 455 miles of narrow gauge; making a total length of 1,400 miles. The rolling-stock consisted of about the same number of carriages and wagons—exclusive of private stock. The engines were in number equal to about five-sixths of those of all the railways in India. There were about 20 points at which the broad gauge and the narrow gauge met, thereby rendering changes of carriages and transfers of merchandise and minerals necessary. The tonnage transferred in the course of a year had varied from about 500,000 tons to about 750,000 tons, and the number of cattle, sheep, pigs, &c., 40,000 animals to 50,000 animals. It would thus be seen that the officers of the Great Western railway had considerable experience in the working of the two gauges and of a break of gauge.

The objections to break of gauge which were most readily apparent, and which had been most dwelt upon in the course of the discussion, were the cost of transfer, the damage to the goods, and the delay consequent on the transfer. His experience, however, prevented him from concurring in some of the strong statements which had been put forward upon those points. The cost of transfer from one gauge to another under certain circumstances might and did become considerable, but where proper accommodation was provided, and where no blockage took place, the average cost of the actual transfer varied within moderate figures which any person of experience in general business might fairly estimate. The cost also varied with the nature of the goods handled, whether pig iron, teas, or furniture. He might state that in the calculations which were made for the Directors of the Great Western Railway Company as to the probable effect which the alteration of the gauge in South Wales would have on the revenue, the money value of the saving to be effected, where transfer would be done away with, and the additional cost which would be incurred where new points of transfer would be created—by the alteration of the portion of the system between Swindon and Milford with the branches—was put down at 5*d*. per ton. It would be safe, however, on similar traffic, irrespective of damage to goods or waste in minerals, to allow 6*d*. per ton.

As to the damage to goods from a transfer, which in the course of the discussion had been stated by some speakers to amount to as much as 2*s*. 6*d*. per ton, his experience did not confirm so large an amount as anything like the average cost; and that it was not, and could not be so great, would be readily understood, when it was considered that the removal of goods from a warehouse to a cart, from the cart to a railway wagon, and from the latter again for delivery, were practically equal to breaks of gauge; and that while a very large amount of transfer business was carried on at all the principal railway junctions in the country—even where the gauges were uniform—no such damage to the goods, on an average, did take place.

It was, of course, true, that in the course of transfer from one gauge to another very serious damage and loss did sometimes occur, but the average cost of the damage depended on the class of goods to be transferred, the accommodation provided for the purpose, the time allowed for the work, and the class of men employed to perform it.

As a proof that the assumption of anything like 2*s*. 6*d*. per ton as the value of the damage arising from transfer was erroneous, he might state, that in 1870, about 200,000 tons—out of the total tonnage transferred by the Great Western Railway Company—were general goods, so that, assuming 2*s*. 6*d*. per ton as the amount of compensation under this head alone, it would have amounted to £25,000, whereas the total sum incurred by the company, in the year, was only about £16,500, and this included not only damages from transfer, but all claims for theft, damages, delay, and loss on 2,944,273 tons of general goods, and 8,000,000 tons of other traffic—so far as the company was liable for any loss—as well as on 2,956,291 parcels, and also on passengers' luggage; showing conclusively that the damage to goods from a transfer was much over-estimated. The truth was, that some of those who were opposed to a break of gauge, under any circumstances, had very much exaggerated the cost and damages arising from a transfer from one gauge to another, while some of those who were defending a policy which would create a break of gauge overrated the importance of being able to show that this was the case, whereas the real objections to a break of gauge under certain circumstances were of a more substantial and different character, although not so readily seen or understood.

With regard to the delay arising from passengers having to change, or from goods having to be transferred from one gauge to another, he might state that the more or less serious nature of that difficulty depended entirely upon the circumstances of the case. Where traffic was not great, when it was regular, and when sufficient accommodation and rolling stock were provided, and where no sudden emergency arose, the delay or inconvenience was comparatively small, except in the case of mineral traffic and heavy or bulky articles. In the west of England, for instance, where the traffic was to a large extent of that character—and possibly not very dissimilar from that of certain parts of India, except that time in transit was a much more important element in England—the delay and difficulties arising from a break of gauge were not of a serious nature.

With regard to the construction of new lines of railway, on a different gauge from that of existing lines, with which they were to form a connection, he could quite understand that there would be and were cases, in every country, in which that was a necessary and even desirable course to adopt; it was so, to some extent, in Great Britain and in Ireland. He knew of one railway on a 3 ft. 6 in. gauge, which was being constructed from the railways on the 5 ft. 3 in. gauge, from Ennis to the coast of Clare; and, if uniformity was not followed out to the extreme in Ireland, the same reasons might to a greater extent prevail in certain districts in India, where, from the nature or amount of the traffic, the character of the country, or other circumstances, narrow-gauge branches would be sufficient for all commercial purposes without any serious countervailing disadvantages.

It had been stated, in the course of the discussion, that the case of the Great Western railway could not fairly be compared with the position of railways in India, a statement in which he, to some extent, concurred; but it had also been said that the Great Western Railway Company, in recently making a considerable alteration in the gauge of their railways, were induced to do so for the purpose of competing with other lines of railway for the traffic of South Wales, and not because there was any serious disadvantage in a break of gauge; a statement which was not correct. Every person acquainted with the position of the railways between London and South Wales must be aware that the Great Western Railway Company possessed, in addition to the broad-gauge line between London, through Gloucester and South Wales, to Milford, a parallel narrow-gauge line through Gloucester, Hereford, and Merthyr to Swansea, which was considerably shorter than the route of any competing company, and by which they had access to all the principal ports, iron works and collieries in the district, and over which the greater portion of the South Wales mineral traffic was still carried. This being so, if there had been no other object in view it would not have been necessary, for the sake of competition, to have altered the broad-gauge lines.

It had also been stated, or inferred, first, that the broad gauge was more expensive to work, and secondly, that it was in other respects a failure, and therefore had to be abandoned. A comparison between the working expenses of the Great Western railway and any other large railway would, however, conclusively show, even when a large mileage of mixed gauge was being worked, that the first statement was not correct. As to the other statement, he could positively affirm that the change of gauge, on certain portions of the line, did not arise from any objections to the broad gauge, other than a desire to prevent a break of gauge. Indeed, some of those, who were best able to express an opinion, considered that the broad gauge, although objected to in mineral districts on account of the additional cost of constructing sidings, &c., had not been tried to anything like the maximum of its capacity for the conveyance of passengers, and that the improved carriages and arrangements which could have been adapted to it could have been made to afford such comfort and accommodation to passengers as had not yet existed in the United Kingdom.

The desirability and even necessity, however, of adopting a uniform gauge throughout South Wales had been long foreseen and looked forward to by the Directors; for although during a portion of the year the traffic was moderately regular, at other times it was fluctuating, and it was therefore frequently found, when this fluctuation arose, or when the traffic had to be carried over distances, sometimes short and sometimes long, that it was impracticable to provide the rolling-stock with regularity, notwithstanding the large amount of stock owned by the company, which was largely supplemented by stock owned by private persons; and thus the transfer stations became blocked; uncertainty, delay, and loss were thereby caused, and a check was given to progress and development, whereby the interests of the districts, the company, and the traders suffered.

The following was an extract from a memorial which was signed by or on behalf of 269 firms of manufacturers, merchants, colliery owners and others, in 1866, addressed to the chairman and directors of the Great Western Railway Company, for the .extension of the narrow gauge throughout the South Wales line:—

"The undersigned, being deeply interested in the minerals, metals and commerce of South Wales, desire respectfully to represent to the Directors of the Great Western Railway Company the serious impediments, inconvenience and loss the commerce of the district is sustaining, in consequence of the broad gauge being, in many cases, wholly inapplicable to their wants: thus confining their communications to very circumscribed limits, arresting their operations, and consequently crippling their trade.

"The transfer of goods, in consequence of the break of gauge at every port and principal station between Milford and Gloucester, is expensive and tedious, entailing, moreover, constant delay in delivery, grievous disappointment, consequent annoyance, and often serious loss to both consignor and consignee; and as regards the great staple of this district, viz. coal, such transfer (involving not only the expense of the operation, but the loss arising from depreciation by breakage) becomes positively prohibitory. The undersigned therefore desire strongly to represent, that the early adoption of the narrow gauge along the whole of the South Wales line is imperatively called for by the necessities of this district."

In consequence of this memorial, and the strong belief that the trade of South Wales could not be properly developed, except on one uniform gauge—it being clear that trade was retarded as well as loss sustained beyond the cost of transfer of the coal, &c.—to overcome the difficulties of the fluctuation of the traffic, the sudden emergencies that therefore arose, and the transfer—the Great Western Railway Company, in the summer of 1872, expended about £600,000 in altering 273 miles of railway west of Swindon, providing extended sidings—rendered necessary by the narrower gauge rolling-stock—and in other matters incidental to the change.

It had been stated in the course of the discussion that the improved position of the Great Western Railway Company was to some extent attributable to this change, as well as to the removal, in 1869, of the broad gauge from the lines north of Oxford and Gloucester; but this was a mistake, as, under any circumstances, the alteration of gauge in South Wales had not been long enough in operation to have had any material effect upon the traffic. The feeling, however, throughout South Wales was universal, as to the advantages which the trade of the country as well as the traffic of the company would derive, from the existence of an uniform gauge throughout the district; indeed, although the alteration of gauge only took place in May, 1872, the ironmasters and others had already benefited considerably by the change.[1]

With respect to the new lines in India, he understood the position to be, that about 5,000 miles of lines had been made, at a cost of about £90,000,000, and that it had been determined to provide 10,000 additional miles of lines, and the question was, whether they should be constructed upon the standard gauge of the existing lines, or upon a new and narrower gauge. It appeared that the proposed lines were so laid out that there would not only be twenty-one points at which there would be a break of gauge, but also—if no mixed gauge was provided—that there would be eleven separate systems having no through communication with one another, and therefore that these would practically possess as few advantages, in respect of through communication, as if they had been constructed upon eleven different gauges. There was no experience of that kind in England, the only case having been that of the West Cornwall railway from Truro to Penzance, which was upon the narrow gauge, while the lines connected with it were upon the broad gauge. When that line became the property of the broad-gauge companies that state of matters was immediately altered. With that exception, the whole of the broad-gauge rolling-stock and the whole of the narrow-

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[1] As instances, it might be mentioned that one firm informed Mr. Grierson that they had, up to the end of that year saved £1,000 by the better working of their trucks; while another well-known firm made such a statement to him on the same subject, that he was induced to write them to ascertain whether he had misunderstood them, and he received the following reply:—

"5, Queen Square, Westminster, S.W.
"*March 3rd*, 1873.

"My dear Sir,

"I have not the slightest objection to your making use of the statement I made to you as to the effect upon us of the change of gauge.

"The expression, however, should be, not 'that it saved us £20,000 per ann.,' but that it made a difference to us in our business of fully £20,000 a year. With this modification, you are quite at liberty to make any use of the statement, and, if you see advisable, I put no restraint on your mentioning names.

"Yours faithfully,
"ALEX. BROGDEN.

"J. Grierson, Esq.,
"Paddington."

gauge rolling-stock had been available for working throughout, on the broad-gauge system and the narrow-gauge system respectively.

From the Paper it would appear, that the main reasons for proposing the construction of the new lines upon the mètre gauge, instead of the standard gauge, was that the existing railways in India had only paid 3 per cent., and that the Indian Government had to make up the difference between that and 5 per cent. In considering that argument, the first question that naturally arose was, whether the existing lines had been as economically constructed as they might have been, or whether any special circumstances had arisen which had increased the cost beyond what would now be incurred, in respect of the new lines proposed to be constructed? Whether this were so or not, it appeared to be an extraordinary and a fallacious argument to put forward, that the gauge of the remainder of a great system of railways in India should be fixed by the amount of dividend which a portion of the system had earned in the earlier years of their existence. If this were a proper principle by which to be guided, then the Great Western railway, which for the last twenty years had yielded an average dividend of rather less than 3 per cent., ought not only not to have been made on the 7 ft. gauge, but should have been made on a 3 ft. gauge; and in the case of the Scinde railway, which had expended upwards of £9,000,000 on 667 miles of railway—but which, according to the last returns, had practically yielded no return whatever—it would follow that the line ought not to have been made at all. If the proposed lines had to be made simply in the interest of those who provided the capital, irrespective of every other object or reason, the question might assume a somewhat different form; but the Indian Government would not only be the owners or guarantors of the capital, but they also represented and were most deeply interested in the land, commerce, and welfare of the whole country, which would, by the construction of railways, be benefited far beyond any difference between the net earnings of the lines and the interest on their cost. That this had been the case in England, was beyond dispute; and even in Ireland, where there had not hitherto been the same development of trade and commerce, the knowledge that the value of railways to a country was not to be measured by the dividends they paid, was shown by the counties, such as Kerry, Galway, Waterford, Limerick, &c., having guaranteed, and now guaranteeing, the interest on the capital, or a portion of the capital, of the lines which had been and were being constructed through those counties; and yet the interest of, and the advantage to the Indian Government in the construction of new railways in India, exceeded that of the Irish counties. The Author, however, had stated that the proposed lines were expected to be "strategically and politically, as well as commercially, useful." Now, if there was one reason more than another which in Mr. Grierson's judgment should weigh powerfully against any break of gauge, on trunk lines, in India, it was that they might be required for strategic purposes. Any state of circumstances requiring the use of the railways for strategic purposes would make it desirable, and probably absolutely necessary, that there should be certainty, rapidity, and the power to make use of every available means of transport; but the contingencies of a state of war on any large scale, coupled with a break of gauge and a comparatively small amount of rolling-stock, would almost assuredly result in confusion, delay, and disappointment.

Allusion had been made by Mr. Hawkshaw to some inquiries and calculations which had been undertaken, to show in what way and in what time large masses of troops could be conveyed from one part of Great Britain to the other, in case of invasion, and as Mr. Grierson was cognisant of the matter, he might state that while the result showed that, with proper arrangements, the movement of troops in the United Kingdom could be carried out with a facility and to an extent which had not been, and probably could not be done in any other country, at the same time, although it appeared that there would be about 10,000 engines, 35,000 carriages or vehicles suitable for traveling in passenger-trains, and 250,000 goods wagons and cattle wagons, available for the purpose, yet in cases of sudden emergency, or in large movements, it was evident that some delay might arise in certain places in concentrating the rolling-stock required for the purpose. If this might be the case, in certain cases, in England, where the amount of rolling-stock was so great, what would be the practical working in India, if the lines were constructed on different gauges, with a limited and isolated amount of rolling-stock, such as would be the case, for instance, on the Lahore and Peshawur line? It had been stated that, on the proposed mètre-gauge line from Lahore to Peshawur, the calculations were made for a provision of only 1 engine and 30 carriages for every 13 miles of railway, and that it would require 200 carriages to convey 1,000 men. If this information was correct, it would follow that—unless such a quantity of spare stock were kept, as would not be required in ordinary times—supposing every vehicle to be available and no irregularity to arise, the largest number of men who could be carried from Lahore to Peshawur, even taking all the stock to be in use in one direction, would be less than 3,000 at a time; while the working of such a long length of single line could scarcely, in practice, be carried on, under great pressure, without some irregularities in the return of the rolling-stock, upon which would depend the further conveyance of troops, stores, &c.

In the event of war in India, either from civil commotion or from an attempt at invasion, the possession of the railways, or the destruction of their rolling-stock, would probably be a specially important object. If the Lahore-Peshawur line was constructed on the mètre gauge, and the stock, or any considerable portion of it, could be destroyed by the enemy, it would amount to the destruction of the railway itself, for all practical purposes. On the other hand, if the line between Lahore and Peshawur were constructed on the 5 ft. 6 in. gauge, the rolling-stock of all the other lines would be available, and trains could be sent forward to Peshawur continuously until the whole movement was completed, the trains standing on and being discharged, if necessary, upon the main line, and without any necessity arising for returning the empty vehicles, or checking the running of trains from Lahore until the pressure was past.

As previously stated, the difference of gauge in the west of England, in consequence of the nature of the traffic and other circumstances, was not seriously objectionable; but, at the same time, his own opinion was that, if at any time during the last ten years or fifteen years there had been any real probability of the railways in that part of the country being required for 'strategic purposes'—as the Author assumed that the new railways in India might be—the difference in gauge in the west of England would not have existed for five years after such an event had been apparent. The Royal Commission on Railways in 1867 reported:—"We are of opinion that the continued existence of the double gauge is a national evil. We think it worthy of consideration, whether it may not be desirable to require the broad gauge to be put an end to; and as the evil has arisen to some extent from the proceedings of Parliament, whether a loan of public money should not be granted for the purpose, on the principle we have suggested for advances to Irish Railway Companies." From Mr. Grierson's experience of the difficulties which had arisen in dealing with the construction of new lines, where two gauges existed, he should fear that, if the proposed new lines in India were made on the mètre gauge, it would become necessary, at some comparatively early period, to consider—almost irrespective of any question as to the working—the desirability of altering one of the gauges on trunk lines. The longer the time before such a determination was arrived at, the greater would be the loss in respect of the rolling-stock.

It appeared to him that if the further railway accommodation in India could only be provided by private enterprise, in the same way that railways had been provided in England, and the capital could only therefore be obtained, if an adequate return for such capital could be insured, and if the traffic of the districts through which the 10,000 miles of railway were about to be constructed would not yield a fair interest on the cost of railways, on the standard gauge, it would then, and then only, be a question of constructing railways on the mètre gauge or of having no railways at all, and in such a position he would distinctly say—although it would be a misfortune to be placed in the position of choosing such an alternative—that the railways should be made, notwithstanding that the evil of a break of gauge was incurred.

If, however, it were admitted that railways would develop the resources of a country, so that although they would not directly pay in themselves, they would enrich the country to an extent far beyond the loss of interest—and if the Government, having the greatest interest in the land and the well-being of the country, and having to provide the capital and the railways, and by so doing, at the same time, secured the necessary means of insuring the peace of the country by the rapidity, certainty, and economy by which troops could be moved—then he would most distinctly say that a break of gauge on trunk lines, such as had been suggested, ought to be avoided. If the question was whether India should have 15,000 miles of railway on two gauges, at a cost of £160,000,000, or the same mileage on one gauge at a cost—even assuming the Author's own figures—of £170,000,000, Mr. Grierson would again say that it would be a misfortune to have a break of gauge for the mere saving of 6 per cent. of the total cost; but if there was any portion of India where there should be a continuous gauge it was, in his opinion, between Calcutta, Kotree, and Peshawur.

Mr. George Turnbull, in a communication authorized by the Council, and through the Secretary, stated that as he had been for many years connected with Indian railways, and had spent above thirteen years in India, employed in their construction and maintenance, he felt it a duty to say a few words on this important subject.

In the early part of the discussion it was put forward by a great advocate of the narrow gauge, that whatever were the technical knowledge of the opponents of the proposed change of gauge, they did not possess such a knowledge of Indian local conditions, or of the administration of a great country, as to render their opinion more than one of the elements in the question. Now he did not concur in that remark, because he held that the general principles of engineering in such questions as that before the Meeting were of universal application, and that the question in itself was one of a purely technical character. He was sure that there was nothing in Indian railways to make them an exception to that rule. He spoke from experience in the matter, as he was well acquainted with the country, having been Chief Engineer on the East Indian railway, and having constructed that line through Bengal, and having had charge of its maintenance after it was opened for traffic. He could confidently assert that there was no special claim for consideration, of matters of gauge, by those who had long resided in India, or by those who had a knowledge of Indian local conditions; but that whatever was good in England was good there, and what was bad in England was bad there also.

The question, as he understood it, was not whether a 3 ft. 3 in. gauge or a 5 ft. 6 in. gauge was the best in the abstract, but whether, having a 5 ft. 6 in. gauge established in India over 5,000 miles, mostly of main lines, and the Government intending to make 10,000 miles of lines more, it was to abandon the 5 ft. 6 in. gauge, adopt the 3 ft. 3 in. gauge, to interpolate a length of 240 miles of mixed gauge on a main line, and to adopt the narrow gauge on the important extension to Peshawur of the greatest main line in India. The objections to a break of gauge, and to a mixed gauge, were so well understood, and had been so fully brought into view and admitted, during the discussion, that it was only the necessity of the most severe economy that would justify the project of the Indian Government. No other plea, but that of economy, had been urged, and there was the greatest difficulty in coming to a conclusion on that point, for the estimates of saving, on excellent authority, varied in round numbers from £200 per mile to £2,000 per mile, which was certainly a most unsatisfactory condition of the question. Moreover, there had been differences of opinion as to the maintenance. General Strachey had alluded to the greater economy of maintenance on narrow-gauge lines; although that officer did not insist upon it, or attempt to prove it. On the other hand, Mr. Douglas Fox stated from his Canadian experience that "there was no appreciable difference between the cost of running a train or of hauling a ton of goods on the 3 ft. 6 in., or the 4 ft. 8½ in., or on the 5 ft. 6 in. gauge." If that were so, the question was narrowed to the cost of construction only. Again, on that point there were discrepancies not easily reconciled; for example, as to sleepers and ballast, it had been said that 8 in. by 4 in. was the section for sleepers for the narrow, and that 9 in. by $4\frac{1}{2}$ in. was the section for sleepers for the broad gauge. That 9 in. depth of ballast was right for the broad gauge and 6 in. depth of ballast for the narrow gauge; a statement which was simply incomprehensible; because all engineers knew that the strength of the permanent way should be in proportion to the weight put upon it, whatever might be the gauge, and that the strength of the permanent way was ruled by that condition alone. The logical conclusions were, that the calculations of saving in construction were not to be relied upon, because they appeared to be founded on different bases, and that the Government of India might well pause before they decided upon the matter without further investigation. He thought it would be found out eventually that the proposed saving was illusory, and had arisen from a well intentioned, but mistaken view of actual economy.

Assuming that the cost of the permanent way and of the bridges was proportionate to the pressure on the rails, a question at once arose whether a saving by the use of light rails and sleepers, and of a thin coat of ballast, where light traffic occurred, would not effect an almost equal economy, and avoid a break of gauge on the main lines?

Not being one of those who had a special bias for any special breadth of gauge, he would guard himself from being supposed to think that the 5 ft. 6 in. gauge was the best or most suitable for India; but 5,000 miles of railway having been constructed on that gauge, he considered that the proof of the estimated saving in the construction of the future 10,000 miles of railway was so unreliable that no prudent administrators could place much faith in it.

Abundant proof had been given, that heavy traffic could be carried upon gauges varying from 3 ft. to 7 ft.; also it was not to be denied that there were places in India where a narrow gauge would be desirable, if a very small saving could be effected, say, even of £50 per mile to £100 per mile; such, for example, as a line to the Sanatorium of Darjeeling, of about 150 miles from the north bank of the Ganges; which, if made on a line going nearly due south from Darjeeling to Caragola Ghaut, opposite a station on the East Indian line, would be of the utmost service, but could never be a main line, and could never communicate with the East Indian railway except by steamer, because the crossing of the Ganges by a bridge was too formidable a work to be undertaken for the use of such a line. India was so vast a country that there were many other localities where the cheapest of all possible constructions should be adopted for keeping open communications, otherwise broken off during the rainy season, where, as in Lower Bengal, there was no material for road-making, except burnt clay and broken bricks, the kunkur or limestone nodules being too expensive, and often not to be found at all. This circumstance, although apparently a matter of detail, was in reality one of great magnitude. The development of Indian railways was undoubtedly impeded, in a most serious manner, by the want of 'feeders,' or roads of communication leading to the railway stations. In many places in Lower Bengal, very populous and very fertile, the roads, so called, were unworthy of the name, being merely formed by cutting a trench on each side, and throwing up a low mound for the use of the bullock carts in the dry season; in the rainy season such a track became nearly impassable, and was often deserted, and new tracks were made through the adjacent rice-fields. It was in such localities and under such circumstances that the cheapest of all railways or tramways would be invaluable. On the other hand, the inconveniences and losses accompanying a change of gauge, or a mixed gauge, on any main lines communicating with each other, were so great as regarded ordinary traffic, to say nothing of the difficulties in the conveyance of troops and war materials, in case of future military operations—a probability which should never be forgotten—that he thought it would be well if engineers, who were authorities in such matters, would enter some protest against the course that was being pursued; and that, as well-wishers to their country, they should at least solicit a reconsideration of this subject, which was of such great consequence to the material advancement of India, and thus possibly prevent a repetition of the serious mistakes which had been made in this and other countries, and which had ended in a return to an uniform gauge, after suffering the punishment of great and unnecessary pecuniary loss.

Dr. Pole, in a communication authorized by the Council, and through the Secretary, stated that he thought it the duty of every one who, like himself, had had to do with Indian railways, to put on record his opinion on the grave question now before the Institution.

He had been greatly astonished at hearing, that the Indian Government had determined, on economical grounds, to alter the gauge, as such a step appeared to him to ignore all the knowledge and experience gained on the subject. He had occasion to study carefully the history of the English gauge question, having been called on to contribute the chapter on the gauges to Mr. Brunel's lately published life of his father;[1] and Dr. Pole had found, what indeed was evident enough as a matter of reasoning, that one of the most positive results brought out by the controversy was the very insignificant influence that the gauge had on the cost of a railway—the real criterion of expense being the carrying power. It had been shown clearly, that if the Great Western railway had been made of the same carrying power as the London and North Western railway, the extra 50 per cent. width of gauge would have added nothing material to the cost. But Mr. Brunel took advantage of the wide base to add 4 ft. in width to all the works, thus giving the line largely increased capabilities; and yet, with this addition, the extra cost was found to amount only to about £300 per mile to £500 per mile![2] And yet they were told now that several thousands per mile were to be saved by the proposed change of gauge in India.

In searching for the origin of this fallacious movement it became clear that a great logical blunder had been committed at the outset. The authorities, having formed a desire, reasonable enough no doubt, to cheapen railways in India, had, as the next step, assumed, that in order to do so it was necessary to narrow the gauge. It was curious to see how, throughout the Indian papers, whenever economy of construction was spoken of, one scarcely ever found the words 'cheap railways,' or 'light railways' used, but always 'narrow-gauge railways;' a strong symptom of a *petitio principii* having forced its way into all the Indian councils. It would seem as if the authorities had referred to Johnson's Dictionary, and finding 'gauge' to be defined as 'a measure or standard,' they had rushed blindly to the conclusion that the gauge was a measure or standard of railways generally, as regarded their calibre, carrying power, cost, and every element involved in them.

This, however, was not so, as was well known to all who had studied the subject. The introduction of the 'overhang' of the carriages at an early period, in order to obtain enlarged carrying capacity with the narrow gauge that had been then accidentally fixed, had taken away the significance of the width between the wheels as a measure of the works. This was obvious enough; for supposing a certain width of carriage to be given, it was evident

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[1] "The Life of Isambard Kingdom Brunel." By Isambard Brunel. London, 1870. Chap. V.

[2] *Ibid.*, p. 129.

that nothing could be gained by the childish and unmechanical step of pushing the wheels closer together under the middle of the carriage; inasmuch as the dimensions of the works must be determined by the size and weight of the vehicle, and not by the cramped width between the wheels. It might be said that the sleepers formed an exception, as they at least might be shorter; but an engineer must be but an incompetent officer, if, having a given load to carry on two points, he could not make his outlay independent, or nearly so, of the width they were apart. For example, the most suitable arrangement for a wide gauge light railway would probably be by laying the rails on longitudinal sleepers, and it was evident that the width apart of these could make but slight difference. As a matter of mechanics and of common sense, the wheels of a vehicle ought to be as wide apart, that is, as near to the edge of the vehicle, as it was possible to place them; indeed, as Mr. Brunel had justly argued, the proper position for them was outside the body altogether, as had been, from time immemorial, the type of all wheel carriages, except those of railways, where the accidental narrowness of the original lines had compelled the adoption of the overhang. It was lamentable to see a wide vehicle standing on a narrow base, and still more lamentable to find the designers and users of such arrangements glorying in what was really a mechanical opprobrium. The only justification for a narrow gauge was when an extremely narrow carriage only was required, and no one would venture to assert that vehicles of 3 ft. wide or 4 ft. wide were suitable for the main lines of our Eastern Empire.

It was no new idea in England, though it might be in India, that if it was desired to reduce the cost of a railway, that might be done independently of its gauge. 'Light railways' of ordinary gauge were common enough. All the early railways were light, while the traffic was yet undeveloped, and there would be nothing new in returning to such lightness, when required, without altering the gauge. Contractors were using light railways every day, but they did not alter the gauge. Mr. Bidder, in his able and exhaustive report[1] of June 14, 1870—which, oddly enough, had been omitted from the published Indian Papers—had given a case where one of the largest companies had lately constructed a line 22 miles long, to accommodate a poor district, with an outlay, including expensive land, of little over £4,000 per mile; it had

[1] Published in Mr. Andrew's pamphlet, "Break of Gauge in India." Second edition. 1873. Page 74.

all the arrangements of the lightest and cheapest possible character, but its promoters had never dreamed that it was necessary to reduce the gauge.

Another case was on the Great Western railway system, where a light branch, of a few miles long, to the fishing-town of Brixham, was worked by a small and light engine. And yet this was on a 7-ft. gauge.

One of the best examples, however, of a light railway on the standard gauge was one laid down by the Duke of Buckingham, on his own estate near Wotton, a few miles from Aylesbury. The Duke, conceiving that many benefits would arise from extending railway communication through his estate, undertook to make a line from Quainton Road Station, on the Aylesbury and Buckingham line, to a place called Brill, about six or seven miles to the west, with a branch to Wotton, one of the Duke's residences. He entrusted the construction to Messrs. Lawford and Houghton, Engineers, of Westminster, and the line was opened about two years ago. It was called the 'Wotton Tramway,' but why this term was used was not clear, as it was as properly a railway as any railway in the kingdom.

It followed pretty nearly the surface of the land, having gradients in some places as steep as 1 in 50, and curves of occasionally 12 chains radius. The rails weighed 30 lbs. per yard, of the bridge section, screwed down to longitudinal sleepers 6 in. by 6 in., with cross ties at every 12 ft. There were no stations, but at each main-road crossing there was a siding for trucks. The entire cost, excluding land, was £1,400 per mile.

The goods traffic consisted of coal, road metal, manure, and general goods, inwards; of hay, straw, grain, timber, bark, outwards; and of cattle both ways. There was also a coaching traffic of passengers and milk. The trucks were of the ordinary kind, borrowed from the adjoining railways, but they were drawn, at a speed of 5 miles per hour to 8 miles per hour, by a special engine weighing about 10 tons or 12 tons. It need hardly be said that the Duke, though, no doubt, he was anxious enough to reduce the outlay, did not commit the folly of altering the gauge.

Another case was of a railway, of a very peculiar and remarkable character, and of which a description was before the Council of the Institution, and would probably be read at a future time. It was the Rigi railway,[1] near Lucerne. In this case the traffic was of an exceptionally light character, only to convey tourists up the moun-

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[1] *Vide* Minutes of Proceedings, Inst. C.E., vol. xxxvi.

tain during the summer. There was only one carriage in each train, and the speed was 3 miles per hour or 4 miles per hour; and, as the line was all on the side of a rock, there was every inducement to reduce the dimensions, and cheapen it to the utmost. Moreover, from the peculiar nature of the railway, it was scarcely to be expected that it could ever be worked in conjunction with any other line.

Here, therefore, was surely a case for a narrow-gauge line, if the system were attended with the wonderful economical advantages claimed for it by the Indian authorities. Yet, strange to say, the Swiss, that eminently practical and utilitarian people, did not see this, but made the Rigibahn only a 'light railway,' of the ordinary gauge.

Railways of this kind had actually been provided for by the Legislature, for in the Regulation of Railways Act, 1868, there were clauses introduced specially authorizing and regulating the construction and working of light railways, but giving no encouragement for altering the gauge.

He might further refer to a Report of a Meeting of the Exeter Chamber of Commerce, in June, 1872, at which Mr. Ellis, the mayor of that city, read a Paper on the subject, after which a resolution was passed directing attention to the great importance of a system of light railways to Exeter and the neighbourhood. Mr. Ellis began his Paper by the following words: "Almost every one is now inquiring what is a light railway?" It need hardly be said that the Chamber of Commerce did not arrive at the answer given by the Indian Government to the same question, namely:—"That it must be a railway of an exceptionally narrow gauge."

What became, therefore, of the Author's assumption, that practically the broad gauge was never adopted, except when broad, heavy vehicles were used; and, that in any comparison of the two gauges, that intention might always fairly be assumed? That might be all very well as an opinion hazarded by an amateur, but both reason and experience showed it to be a fallacy.

It had been said by Mr. Gladstone in the House of Commons a short time ago, that "in the battle of the gauges, fought in this country thirty years ago, nothing could be more decisive than the victory of the narrow over the broad, and of uniformity over diversity." Now, as Dr. Pole claimed—as he had before stated—some knowledge of the proceedings in question, he must assert that this statement was calculated to mislead. What Mr. Gladstone called the victory of the narrow gauge over the broad gauge did not arise from any inferiority of the broad gauge, or any superiority of the narrow gauge; on the contrary, the advantages of Mr. Brunel's system were fully borne out by experience. The victory was wholly and solely due to the impossibility of tolerating a break of gauge. This it was which abolished the exceptional system in the North, and would probably, ere long, abolish it in the West also. And it did not require a great stretch of imagination to anticipate a similar result in India. The time would come when, if the traffic extended, the break of gauge would be found intolerable there also, and then either the narrow gauge must be widened, or the broad gauge be narrowed, and the Indian railway system would become the laughing-stock of the world.

He might add that he had now charge of the Imperial Railways of Japan, which had been laid out, before his connection with them. on a gauge of 3 ft. 6 in. He did not find this to be any advantage, but the reverse. He had reduced the vehicles to as small a size as he dared, but he could not provide for the traffic with a less width of vehicles than about 6 ft. 6 in.; and under this condition, the narrowing of the wheel breadth only gave rise to bad and inconvenient construction, both of the engines and carriages, while it saved nothing in the cost. It was under consideration whether the gauge should not be widened before the evil became too much extended.

Dr. Pole must conclude by adding his protest to that of all other Engineers, against the narrowing of the Indian gauge, unless it could be conclusively shown, which certainly had not been done, that the desired economy could not be obtained in any other way. The subject had been much complicated by masses of figures, exhibiting, no doubt, some discrepancies, according to the views held by different individuals; but there was no technical mystery about it, and the common-sense application to it of ordinary mechanical principles and ordinary laws of construction would, he was convinced, suffice to show that the Indian project was founded on a delusion, and that the judgment dictated alike by reason, by experience, and by the universal opinion of those most competent to judge, was the correct one.

Mr. J. E. Tanner, in an authorized communication through the Council, stated that the Author, while asking for pity for the Indian tax-payers, should have reminded those who were unacquainted with India that the guaranteed railways were the pioneers of railway communication in that country. The shareholders of those lines had many difficulties to contend with, and part of the capital on which interest had now to be paid had been spent in overcoming them. In fairness he should also have stated that the Indian Government and the tax-payers reaped advantages from the railways beyond the $3\frac{1}{2}$ per cent. which they earned, and that at the same time those advantages occasioned a loss of profit to the railway proprietors; as also that some loss accrued to those railways that were under construction during the Mutiny.

The railways in India did not succeed turnpike roads and canals as in England, but often supplied the place of so-called 'roads' without bridges or metalling, consequently all skilled labour had to be taught. The skilled labour that had been taught by the guaranteed railways had become remunerative to the country, although the country might not at present have entirely recouped the money spent for their education.

Some of the railways were constructed at a considerable distance from the seaboard, causing not only excessive cost for transport, but a heavy item for delays in delivery. Mr. Tanner had seen a locomotive drawn by bullocks two hundred miles over an unmetalled road ankle-deep in dust; and convoys of carts thatched over in the jungle, waiting for the rains to cease before they could proceed on their journey, while platelayers and others who were in want of the materials, which those carts ought to have been conveying, were standing idle. Future railways in course of construction would not have to contend with such disadvantages, nor with the almost total want of skilled labour then experienced.

Those who knew India before the railways were in existence would recollect the relays of horses at every sixth mile, for the postal service of letters alone; and the relays of bullocks at every tenth mile for heavier parcels, newspapers, and such light merchandize as could afford the charge. The railway companies, by their contract, were obliged to carry the postal service for nothing, and even to provide vans—if not sorting vans. By the construction of the guaranteed railways the expense for the maintenance of horses, bullocks, carts, wagons, and the establishment previously necessary, had been saved for more than 5,000 miles.

The economy that accrued to Government by moving troops by rail, instead of by the costly establishment necessary for marching, had been already alluded to. The Author, to have drawn a fair comparison, might have shown what those savings amounted to, in order that they might have been added to the $3\frac{1}{2}$ per cent. earned by the railways.

With regard to break of gauge, Mr. Tanner had lived long enough in India to know that an order by the Governor-General in Council was not to be argued against. But those persons who constituted the Governor-General in Council might after a time retire, and their successors might possibly not feel justified in continuing the construction of the railways upon the scheme so strenuously advocated by the Author.

Mr. Tanner would give an instance. The Sutlej bridge was built in the most exposed part of the river, because the Governor-General in Council ordered it; the object being that it might be under the guns of the fort at Phillour, which was always to be garrisoned from an English regiment. The Governor-General in Council had changed before the first girder was in place, and a new order removed all the guns and the contents of the magazine to Ferozepore, 80 miles away, and the English troops were supplanted by one company of native infantry.

With regard to width of gauge, arguments had been adduced for and against the narrow gauge and the broad gauge—but had they been carried far enough? No one could gainsay that a narrow-gauge line could be made at less cost than a broad-gauge line, as far as the construction of the line went; but the saving was so little, that the extra expense for rolling-stock necessary for the narrow-gauge line to give equal carrying capacity would possibly counterbalance the saving effected.

Mr. Tanner had lately been engaged by Government to furnish two estimates for a single line of railway in one of the colonies. One on a gauge of 3 ft. 6 in., and another on a gauge of 4 ft. 8½ in. As there was no railway in the colony, there was no question of break of gauge, and the relative advantages of both gauges could be fairly weighed. The estimates were prepared from actual survey, and every minute detail was considered. The results might therefore be interesting.

The data started with, were as follows :—The engines were to be 6 wheeled, coupled; to weigh 18 tons, and to be suitable for a speed of 25 miles per hour. The load on the carriage wheels was to be 3 tons. The rails were to weigh 55 lbs. per yard. For the 3 ft. 6 in. gauge, the width of the bank was to be 14 ft. 6 in. at formation level. The width of the carriages was to be 6 ft. 4 in., and the length, 15 ft. For the 4 ft. 8½ in. gauge, the width of the bank was to be 15 ft. 9 in. at formation level. The width of the carriages was to be 8 ft. 6 in., and the length, 15 ft.

The result of the estimates gave as the cost per mile for the construction of the line alone :—

	£	s.	d.
On the 4 ft. 8½ in. guage.	5,139	13	9
„ 3 ft. 6 in. „	4,977	15	0
	£161	18	9

or a saving in construction of the line by adopting the 3 ft. 6 in. gauge of 3·17 per cent.

The cost per mile for construction, including stations, telegraph, and everything except rolling-stock, was as follows:—

	£	s.	d.
On the 4 ft. $8\frac{1}{2}$ in. gauge	6,610	18	7
„ 3 ft. 6 in. „	6,445	8	3
	£165	10	4

or a saving in favour of the 3 ft. 6 in. gauge of $2\frac{1}{2}$ per cent.

Before comparing the rolling-stock of the two gauges a few words of explanation were necessary. Undoubtedly a narrow-gauge wagon, when carrying material such as stone, ballast, &c., could carry its load with less dead weight of wagon, and was therefore preferable and cheaper for mineral traffic; but for passengers the same floor area was required for both gauges. For light goods, such as loose cotton, the broader gauge gave better carrying capacity, for if there were no over bridges the load could be piled up higher, as well as wider. Floor area was therefore taken as the basis for comparison in the two estimates. The rolling-stock for the 4 ft. $8\frac{1}{2}$ in. gauge amounted to £17,177, and that for the 3 ft. 6 in. gauge to £19,012; showing a saving of $10\frac{1}{2}$ per cent. in favour of the 4 ft. $8\frac{1}{2}$ in. gauge for equal carrying capacity. The total cost of the railway, with all accessories for traffic, gave a result in favour of the 3 ft. 6 in. gauge of 0·72 per cent.

The traffic estimated for was less than there would be in a very short time after the line was opened for traffic. He believed the rolling-stock would then require to be doubled. Under those circumstances the result would then be in favour of the 4 ft. $8\frac{1}{2}$ in. gauge. All renewals for wear and tear would necessarily be in favour of the broader gauge. The railway referred to was for a special class of traffic, namely, that of carrying sugar hogsheads. A truck or wagon of the 3 ft. 6 in. gauge could only carry 3 hogsheads, while those of the 4 ft. $8\frac{1}{2}$ in. gauge could carry 6 hogsheads. When this was taken into consideration, the result of the estimates was in favour of the 4 ft. $8\frac{1}{2}$ in. gauge to the extent of 1·55 per cent. of the total cost.

Having spent fourteen years on the construction of Indian railways, he knew the disadvantages which those constructing them had to contend against. No fair comparison could be arrived at, by saying "the existing railways cost so much per mile; and our estimate is for so much a mile." A true comparison could only be arrived at by taking the actual quantities of a length of line that had been executed, and by putting the same price against each item of work in the estimate for the proposed line. Surely it would be worth while to make such a calculation before embarking on a change of gauge for 10,000 miles. If such a comparison was made, he was certain the great saving anticipated by the Author would turn out to be almost visionary.[1]

Mr. W. T. Thornton, partly reading from copious notes, said that rather a heavy task had devolved upon him. He had to answer a large number of adverse speeches. To do so with any adequacy would require all the time that he could warrantably occupy, and at least all the strength which he possessed, so that he had better not waste any of either in prefatory remarks, but address himself at once to the business in hand.

It would be convenient to divide his opponents into two classes—those who had not met him with arguments, and those who had; and in the former category he should take the liberty of placing his excellent friend Mr. Andrew, and also Mr. G. P. Bidder. Both of those gentlemen seemed to have taken a hint from the well known story of a leading barrister, who, having risen in Court to answer the case for the prosecution, had a paper placed in his hand by his legal prompter, containing the words, "No case: abuse plaintiff's attorney." Changing plaintiff's for defendant's, this was what they had done. Mr. Andrew's abuse was, indeed, of a very mild description, and did not go much beyond likening Mr. Thornton to Rip Van Winkle, and suggesting that he must have been asleep for the last five-and-twenty years, and that he was therefore ignorant of the disasters with which the 'war of gauges' had been attended in this country. He must own that he could scarcely venture to pay off Mr. Andrew in kind. His excellent friend was very generally understood to be at all times pretty wide awake. Still, if it were possible to imagine him to have been caught napping, Mr. Thornton should really have thought

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[1] As it had been stated by General Strachey (page 264) that, "until the Government of India announced its intention of carrying out narrow-gauge railways, as the only apparent means of obtaining cheap railways, none of the Engineers of the Indian lines—exclusive of the Oudh and Rohilkund Company and the Indian Tramway Company—suggested the construction of light or cheap lines, or admitted that they were possible." Mr. Tanner submitted a copy of a Report made by him to R. Saunders, Esq., Postmaster-General, Punjâb, dated December 6th, 1861, which Mr. Tanner requested might be printed in the Appendix. It would be seen that in that Report he did, so early as 1861, propose a light railway, and light engines of the normal Indian gauge.—*Vide* Appendix VI.

that on this occasion Mr. Andrew had been talking in his sleep. Mr. Thornton could not otherwise conjecture how a person of Mr. Andrew's acuteness could refer to the English battle of the gauges by way of thereby disparaging the narrow gauge. Surely he could not require to be reminded that in that battle it was the narrow gauge that won, and the broad gauge that was vanquished; so that, if any inference in regard to India was to be drawn from the case of England—not that the two cases were in reality at all analogous—that inference plainly was that, if in India the two gauges were ever pitted against each other, as they had been in England, the narrow gauge would be again victorious.

The personal remarks of Mr. Bidder were of a more decided character, intimating quite unequivocably that, in his opinion, Mr. Thornton was not an ordinary fool merely, but the very 'genius of folly.' He did not suppose that Mr. Bidder meant any harm by that. To talk in that style was very likely only a way he had—a sort of playful chaff. At any rate, Mr. Thorton had no desire to resent it. On the contrary, and on the principle of returning good for evil, he proposed before he had done to give Mr. Bidder, in exchange for his chaff, some solid, substantial grains to digest and ruminate upon.

Turning now to his argumentative opponents, Mr. Thornton was glad to observe that they had directed their chief assault against what had been previously admitted by him to be the key of his position, namely, the question of economy. True, if beaten there, he must acknowledge himself to be beaten all along the line, without one rallying point to return to. But he had no objection to be beaten, if he could be shown to deserve defeat. Contending as he was, not for victory—not for any foregone conclusion—but for truth, whatever the truth might be, he could not but be anxious that, if in error, his error might be exposed. Still, on the question whether he was beaten or not, he requested the Institution to suspend its judgment until they had heard him out.

In pressing the plea of economy, another person in his place might perhaps have engaged extensively in independent calculations, going in largely and learnedly for width of embankments, depth of ballast, sectional area of sleepers, and what not; and, by computing how much this or the other detail would cost on the broad gauge and on the narrow gauge, have shown how much less the aggregate cost would be on the latter than on the former. This was what a professional expert might have done, but which he did not attempt to do, for the very sufficient reason that he could not have done it if he had tried, since, so far from pretending to be a professional expert, he frankly confessed himself to be an unprofessional ignoramus, or, as plain-spoken Mr. Bidder might say, a mere fool in technicalities. Besides, there would have been no use in doing it, even if Mr. Thornton had been able, for his calculations would infallibly have been disputed at every step, and at the end of them he should have been as far as ever from having established any premises in which the opposite side would have acquiesced. But without some premises, common to both sides, there could be no profitable discussion; so, since he could not hope that any data offered by himself would be accepted, he had no alternative but to accept those which had been put forward by his opponents.

He found that two Engineers of the very highest eminence—of the eminence implied by their having been selected by the Institution as its Presidents—had each of them carefully estimated the cost of railway construction under two different sets of conditions—or rather, he should say, of conditions similar in other respects, but different in this: that in the one case a 3 ft. 6 in. gauge, and in the other a 3 ft. gauge, was assumed. He alluded, of course, to Mr. Fowler and to Mr. Hawkshaw. Now there was more than one way in which Mr. Thornton might have dealt with those gentlemen's estimates. In both, the narrow gauge was credited with considerable, but different, amounts of saving—in Mr. Fowler's estimate, with £866 per mile; in Mr. Hawkshaw's estimate, with £760 per mile. Mr. Thornton might not unfairly have taken either of those amounts, and by making certain additions thereto, on grounds which he should presently advert to, have obtained a much greater total than he had actually claimed. That was what he might fairly have done, if his desire had been merely to make a fair show in figures. But that he did not do. Mr. Fowler and Mr. Hawkshaw differed not more as to the total amount of saving than as to the nature of the items on which saving was to be allowed; there being only four items admitted by both, namely, earthwork, bridgework, sleepers and ballast. Mr. Thornton began, therefore, by restricting himself to those four items; nor did he take even the highest of the totals which he found allowed upon those items, but only the mean between the two, and then to this mean he had added not the whole of what was admitted by his authorities on other items, for he rejected some of those other items altogether. He made additions in respect only of those further items which, although included by only one or other of his authorities, as the case might be, ought manifestly to have been included by both, and could not have been omitted by either, except through inadvertence. By this means, and by allowing further for the superior cheapness of a mètre, or 3 ft. $3\frac{3}{8}$ in., gauge, over the 3 ft. 6 in. gauge assumed by his authorities, he obtained £1,000 per mile as the average saving obtainable by the adoption for the Indian State railways of a light mètre gauge, instead of a light standard gauge. He said average saving: of course he agreed with Captain Tyler, that the actual saving would not be the same on all lines, but would vary with the character of the country and other circumstances, being sometimes more and sometimes less than the sum mentioned; but Captain Tyler would, he thought, admit, on reflection, that this was a reason not the less, but the more, for adopting an average in reference, not to any particular mètre-gauge line, but to all mètre-gauge lines in general.

While working out, as above, his total of £1,000 per mile, Mr. Thornton fancied, in his simplicity, that he was displaying an exemplary, an almost chivalrous, moderation; and was, therefore, proportionally disappointed—not to say disgusted—to find, when the matter came to be discussed, that his critics, with one accord, began to take exception to every one of the details of which that total was composed. Mr. Harrison, who led the charge at this point, with Mr. Bruce bringing up the rear, considered that he had been much too greedy in accepting at Mr. Hawkshaw's hands £10 per mile for land, seeing that Major Bonus, in his estimate for the Indus Valley line, had shown that 13*s.* 6*d.* per mile, or, as Mr. Bruce had it, more nearly 10*s.* per mile, was the maximum to be allowed. Major Bonus was an Indian Engineer officer of well-earned repute; and Mr. Harrison seemed to Mr. Thornton to exhibit a very just discrimination in preferring, on questions connected with Indian railway construction, the opinions of experienced Indian Engineers to those of the ablest members of the profession who had never visited the East. Mr. Harrison had, however, misunderstood Major Bonus's meaning to an extent not very remarkable in one who did not pretend to have any special knowledge of India, but somewhat curious in the case of Mr. Bruce, who ought to have known—and no doubt did know—a great deal about that country. When giving Rs. 27, or £2 14*s.*, as the price of an acre, and therefore 13*s.* 6*d.* as the price of a quarter of an acre, Major Bonus was speaking, not of India generally, but only of that territory—for the most part mere sandy desert—through which the Indus Valley railway would run. But Mr. Bruce, who had so skilfully conducted the Great Southern of India line from Trichinopoly to Negapatam, through the garden-like luxuriance of the Cauvery

Delta, ought not to require to be told that there was other soil in India besides sand, and that to judge of the value of the land that would have to be taken up for State railways in Northern Bengal, or the Dharwar cotton-fields, by its value between Mooltan and Hyderabad, was about as much to the purpose as it would be to suppose that the Metropolitan Railway Company and the Highland Railway Company got their land at the same rates per acre. It so happened that in certain instances—very exceptional ones it was true—the Government of India had to pay for the land presented by it to guaranteed railway companies no less than £725 per acre and £1,099 per acre, and this for areas of 141 acres and 61 acres respectively. After all, the figures objected to were not his figures, but those of Mr. Hawkshaw; but still, unless Mr. Harrison and Mr. Bruce could show better reason for questioning the correctness of Mr. Hawkshaw's allowance of £10 per mile for land, Mr. Thornton should not consider himself bound to surrender any part of it, although to part with the whole would not cause him any very great pang.

In regard to earthwork, Mr. Harrison practically agreed with Mr. Fowler—working out the sum for himself and producing a result of £36 15*s.* per mile, or within five shillings of Mr. Fowler's estimate of £37 per mile. Mr. Bruce, indeed, allowed only £33 per mile, differing therein both from Mr. Fowler and Mr. Harrison, and still more widely from Mr. Hawkshaw, who put down £100 per mile on the same account; so that, having here three to one against him, Mr. Thornton concluded that Mr. Bruce must give way. On the subject of bridges, Mr. Harrison admitted that he had no means of judging whether Mr. Hawkshaw's £50 per mile or Mr. Fowler's £83 per mile were right, but Mr. Harrison added, that he was disposed to err on the right side—to wit, that of superior strength, and therefore that he inclined to Mr. Hawkshaw. Now Mr. Thornton, feeling conscientious scruples against erring on either side, had gone midway between Mr. Fowler's estimate and Mr. Hawkshaw's estimate, and so had arrived at £66 per mile, and whoever bethought him of the proverb of his schoolboy days, "*In medio tutissimus ibis*," would probably consider that in so doing Mr. Thornton had selected the safest path. Mr. Bruce, at any rate, said nothing about bridgework; so it was to be supposed that his silence might be taken for acquiescence.

Mr. Bruce remarked, that he had put the bridges at £20 per mile, and given the details.

Mr. Thornton. In respect, however, to the far more important items of sleepers and of ballast there was universal disagreement.

Mr. Fowler on those accounts allowed £503 per mile; Mr. Hawkshaw, £200 per mile; Mr. Harrison—if Mr. Thornton rightly understood him—£257 per mile; Mr. Bruce begrudged £126 10*s*. per mile. These varying figures were the results of equally varying considerations, affecting sundry knotty points as to which Mr. Bruce questioned the sense of Mr. Fowler's decision in one instance, and denied it altogether in another. Such matters were too high for Mr. Thornton's comprehension; he did not profess to be able to attain to them, though he should have a word or two to say presently as to the way in which they had been treated.

Intermediately, however, he must touch upon two or three other matters. One was the saving on engineering and agency, respecting which Mr. Harrison took no objection to the rate of 17½ per cent. adopted by Mr. Fowler, neither did he deny that 17½ per cent. upon £497 came to £87, the exact sum given by Mr. Fowler and accepted by Mr. Thornton. Mr. Harrison proceeded, however, to observe that there were certain details, such as the setting out of the line, the preparation of plans and the estimate of all the works, the cost of which would be the same whether the gauge were broad or narrow, and upon the cost of which, therefore, the charge for engineering would likewise be the same in both cases. Now, no doubt upon all expenditure, common to both gauges, the same percentage charge for engineering would come to the same thing for both; but why the narrow gauge should not save the whole charge for engineering, in respect of an expenditure of £497 per mile, which was not common to both gauges but which applied to the broad gauge alone—why, as Mr. Harrison said, a large deduction should be made from the saving of £87 per mile claimed by Mr. Thornton on that account, Mr. Harrison did not explain; and what was still more in need of explanation was that Mr. Bruce, though professing to follow Mr. Harrison, was not contented with insisting on a large deduction, but required Mr. Thornton to leave out the saving altogether. The truth was that, instead of reducing, he ought greatly to have increased his claim for engineering. He ought really—according to Mr. Harrison—to take 17½ per cent., not merely on the £497 per mile aforesaid, but also on the sum total, amounting more nearly to £1,000 per mile of all the savings, other than those for engineering and agency, with which he had shown that the narrow gauge ought to be credited.

Then, at Mr. Hawkshaw's suggestion, he had taken for reduced cost of annual repairs of a narrow gauge line £10 per mile, and had capitalised that annual saving at twenty years' purchase—

thereby obtaining a total on the item of £200 per mile. Mr. Harrison approved of the rate of £10 per mile, but both he and Mr. Bruce disapproved of its capitalisation on the ground of its not being an ingredient in first cost. But surely, supposing the price of a perpetual annuity of £10 to be £200, it made no difference whether £200 were paid down at once or £10 per annum were paid for ever afterwards, or, conversely, whether £10 per annum were saved for ever or £200 were saved at once. But if so, Mr. Hawkshaw was, Mr. Thornton submitted, perfectly right in that respect, and Mr. Harrison and Mr. Bruce were right only so far as they agreed with Mr. Hawkshaw.

Then came the vexed question of curves. Under this head Mr. Fowler had allowed nothing, because, as he said, in his own practice, in this and in other countries, he had never met with even a single case on which he should have adopted a different curve merely in consequence of gauge. Mr. Hawkshaw, however, even when estimating for a narrow-gauge extension of the Eastern Bengal railway through an almost level country, had allowed £200 per mile for the saving by use of sharper curves; though it was true, he now said, that he never expected so large a saving to be realised. Mr. Harrison also expressed a doubt whether this saving of £200 per mile could by any possibility be applied to the whole 10,000 miles of railway to be made in India; thus, by implication, intimating that Mr. Thornton had so applied it; while Mr. Bruce likewise left out the £200 per mile, which he, too, supposed to have been added by Mr. Thornton for curves, because he knew that "in ninety-nine cases out of one hundred in India, in the matter of such curves as they required, they would not save anything at all." Upon all which Mr. Thornton had first to remark, that not £200 per mile, but only £100 per mile, or only one half of what Mr. Hawkshaw, two years ago, calculated might be saved, by means of sharp curves, even in the dead level of Northern Bengal, was added by Mr. Thornton as the probable average on 10,000 miles of railway, a considerable portion of which would traverse exceedingly hilly and even mountainous country.

He would now mention one or two facts, which might perhaps suggest that Mr. Harrison and Mr. Bruce had been somewhat hasty, in deciding that there was no difference as to curves between broad gauge and narrow gauge, and that Mr. Hawkshaw had been equally hasty in abandoning the more correct opinion on the subject which he until lately entertained. Mr. Thornton supposed he might assume that on none of the existing broad-gauge lines of India were the curves anywhere sharper than on the Thull and

Bhore Ghaut sections of the Great Indian Peninsula line, where the sharpest curves were only 15 chains radius—of which, moreover, there were but 2, all the rest being of at least 20 chains radius—and where, by-the-way, there were more than $2\frac{1}{2}$ miles of tunneling; and the average cost of construction was between £48,000 per mile and £49,000 per mile. Now on the Punjâb Northern railway, there was a section 70 miles in length, between Jhelum and Rawal Pindi, described as "wild, hilly, and broken to an extent rendering a railway a most formidable undertaking." On that section, while as yet it was supposed that the standard, or 5 ft. 6 in., gauge was to be adopted, the Engineer who surveyed the section, assuming a radius of 20 chains as his minimum, reported that extensive deviations of $22\frac{3}{4}$ miles in all would have to be made. The same Engineer, however, having been thereupon informed that the mètre gauge, and not the standard gauge was to be adopted, and that his ruling curve was to be $4\frac{1}{2}$ chains radius, made a new survey, and then reported that it had been found practicable to reduce the $22\frac{3}{4}$ miles of deviations previously deemed necessary to little more than $2\frac{1}{2}$ miles; and that this had been done without going below a 5 chains radius, of which, however, there were 19 curves. What had here been the consequent saving Mr. Thornton would leave others to calculate; but no doubt it must have been something very considerable indeed; and in all probability still more considerable savings of the same kind had been, or would be, found practicable on the Ghaut sections of the Indore and Carwar lines, where much wider scope for sharp curvilineation ought, apparently, to be afforded than on the worst portions of the Punjâb northern line. He might however mention that on the Carwar line there was, in one place, an unbroken incline of 1 in 40, which extended for nearly 4 miles, with curves of 5 chains radius; those curves of course implying an immense saving in the heavy work, which the standard-gauge curves of 15 chains radius, or 20 chains radius would have necessitated. It was quite clear, then, that on Indian mètre-gauge lines generally there must be some sensible average saving per mile by reason of curves. Very likely that saving might be a good deal below the £200 per mile, at which it had been hypothetically put by Mr. Hawkshaw, who, however, in suggesting that amount, was clearly much nearer the truth than Mr. Harrison and Mr. Bruce, who put it at nothing. Whether Mr. Thornton, in putting it at £100 per mile, or as nearly as possible half-way between nothing per mile and £200 per mile, was not likely to be nearest of all to the truth was a question on which modesty forbade him to decide.

In answer to a question by Mr. Harrison as to the authority upon which he had stated that 20 chains radius was fixed as the minimum, Mr. Thornton explained that it had not really been so fixed, but that the Engineer thought it was. On the Bhore Ghaut, of the Great Indian Peninsula railway, the sharpest curve was 15 chains radius, and there were only two such, none of the others being below 20 chains radius.

Returning to the items of sleepers and ballast, what hopeless discord of opinion was there exhibited! Mr. Hawkshaw differing widely from Mr. Fowler, and Mr. Harrison and Mr. Bruce disagreeing between themselves in all else, and agreeing only in pooh-poohing Mr. Fowler, and by implication Mr. Hawkshaw also. Well, very likely Mr. Fowler, if he had been present, might in his turn have pooh-poohed Mr. Harrison and Mr. Bruce. But what construction was an impartial outsider to place on such universal pooh-pooing—what but that in all probability there was on the whole very good cause for it? Of the four eminent Engineers concerned in it, every one was completely at variance with all the rest. Only one, therefore, out of the four could possibly be in the right, while the other three must necessarily have been in the wrong; and the odds were that all four were in the wrong, since there were no three amongst them who did not pronounce the fourth to be so. At any rate, eminent as all four authorities were—'engineering giants,' as Mr. Danvers, without much exaggeration, had styled them—no one of them could prudently be here accepted as a guide, except in so far as his dicta were borne out by fact. But of fact, unfortunately, there was very little available; Mr. Bruce alone having hitherto attempted to adduce any. The latter gentleman, however, having obtained the estimates for 216 miles of mètre-gauge railway, described as in process of construction in the south of India, had examined those estimates to see what would be the extra cost of making the railway on the broad gauge, and he had calculated that the extra cost per mile would be £27 10*s.* for ballast and £99 for sleepers. This he said was not an idea but a fact. How was it a fact? The only fact apparent was, not that the thing was so, but that he had calculated that it would be so. But might it not possibly be equally the fact that he had made a miscalculation? By reducing to a minimum the saving on a variety of other items, as well as sleepers and ballast, and by ignoring some important items altogether, he made out that the difference of cost, between the mètre gauge and the standard gauge in one special locality, would be under £200 per mile, and then he assumed that the same would be the total average saving all over

India. But to the one single, so-styled, fact appealed to by him in support of that view, Mr. Thornton was in a position to oppose a counter-fact of the same description, but much stronger of its kind. In another part of India, namely, in the Punjâb, the difference of cost between the mètre gauge and the standard gauge for the lines between Peshawur and Lahore, and between Mooltan and Kotree, had quite recently been estimated, not by Engineers in England, many thousands of miles off, but by Engineers on the spot, and by Engineers, too, whose predilections were by no means in favour of the mètre gauge in that quarter, and the result had been to show that the standard gauge would cost £721,000 more than the mètre gauge. But £721,000, divided by 773 miles—the aggregate length of the lines estimated for—gave, not Mr. Bruce's £200 per mile, but £930 per mile; just £70 per mile less than the £1,000 per mile claimed by Mr. Thornton. But Mr. Bruce's total being thus presumably so very far below the reality, the separate items, or some of them, composing that total must be presumed to be equally erroneous. Either he must have materially understated the savings on sleepers and on ballast, or some others of the savings which he had allowed, or there must be some items over and above those of engineering, agency, maintenance, renewal and sharp curves, already specially adverted to, which he had altogether omitted to take into account. Whether his faults of commission or of omission were the more important was not for Mr. Thornton to say. It was a matter for theoretical investigaton, on which he should not venture; but setting theory on one side, one thing to which he desired particularly to invite attention was that, so far as facts could be brought to bear upon the matter, those facts were much more nearly corroborative of his total saving per mile of £1,000, than of Mr. Fowler's £860, Mr. Hawkshaw's £760, Mr. Bidder's £600- Mr. Harrison's £400, or Mr. Bruce's £200; and further, that, though Mr. Thornton's figures were nearest of all to the mark, Mr. Fowler's were the second nearest.

In answer to a question, Mr. Thornton said the weight of the rails was assumed to be 40 lbs. per yard in all cases.

Considering his fundamental position to be thus far sustained by fact, he did not think he should risk much by asking the Meeting to decide whether that position had hitherto been damaged. Considering how numerous, how able, and how outspoken had been its critics, he might fairly take for granted that pretty nearly all that could be said against it had already been said; but would any one assert that it had been in the slightest degree shaken? Would it, at any rate, be said that adequate reason—or, rather, the slightest shadow of reason

—had been shown, why the figures of any one of his critics should be substituted for his? If it was thought there had, let him ask, whose?—which of the many utterly irreconcilable totals did the Meeting prefer? Was it Mr. Bruce's, or Mr. Harrison's, or Mr. Bidder's, or Mr. Hawkshaw's, or Mr. Fowler's? Probably time might be necessary to determine. But while the mind of the Meeting was being made up, it could not be denied that he was entitled to adhere to his saving of £10,000 per mile or of £10,000,000 on 10,000 miles; nor, what was infinitely more to the purpose, that the Government of India was likewise warranted in provisionally adopting and acting upon those figures.

Here, as to the general question, the defence of the Indian Government might be safely rested. Having reason to believe that to construct the State railways on the standard gauge instead of on the mètre gauge would involve an additional expenditure of £10,000,000, it might irreproachably decide not to make State railways at all, rather than make them at such a cost. It might irreproachably consider that it had done enough in taxing its subjects to the extent of £1,600,000 per annum, for the 5,000 miles of railway already constructed, without, by constructing 10,000 miles more, increasing that load of taxation to £2,100,000 per annum. Many gentlemen present might think that, in so deciding, Government would decide wrongly. Some gentlemen present had distinctly intimated that the Indian tax-payer—"this very pitiable and most interesting tax-payer," as in not quite the best possible taste he had been designated—should be disregarded in this matter. That, however, was a question which, as even those gentlemen would probably admit, was one rather for the statesman than the engineer, and one of which men with the statesmanlike qualities and experience of the Duke of Argyll, Lords Lawrence, Mayo and Sandhurst, the late Sir Henry Durand, Sir Henry Maine and Sir John Strachey were, on the whole, likely to be more competent to judge than the purely professional tribunal to which Mr. Lee Smith would refer it, even though that tribunal were composed of the 'élite' of the distinguished men who were now sitting, or had hitherto sat, in the President's chair, or around the council-table of the Institution he was addressing.

Even though it were established that, unless made of the standard gauge, by an outlay upon them of an extra £10,000,000, the projected State railways would not adequately answer their purpose, that might be a very good reason for making no State railways at all; but it would be no reason for making the State railways of the standard gauge. The same remark held good of a break of gauge. That a break of gauge was, abstractedly, a great evil, was not denied. That it must sensibly impair the utility of most of the projected State lines, was not denied. But even though, instead of merely impairing, it altogether destroyed their utility, it would not be a reason for making them of standard gauge. In the actual circumstances of the case, the choice, as he had said in the Paper, was not between a broad gauge and a narrow gauge, but between a narrow gauge and no gauge—and no railways.

Of course, however, he was not admitting that mètre-gauge lines would not, for all carrying purposes—in other words, for all purposes whatever—answer perfectly in India. Scarcely any one who had spoken in the course of the discussion denied it—certainly not Mr. Bruce nor Mr. Harrison; while General Strachey had stated how the average daily traffic of the most heavily worked standard gauge line in India—the East Indian line—could be carried on the mètre gauge by 12 trains each way, of 17 vehicles each, the vehicles, too, being not more than half filled. True, as Captain Tyler had objected, a railway should be adapted not for average traffic, but for maximum traffic; but then, Mr. Thornton would ask Captain Tyler how soon he expected the maximum traffic of the best of the projected State lines to exceed the average traffic of the East Indian line, considering how comparatively poor and thinly peopled were the territories proposed to be traversed by the State lines?

Mr. Thornton had already said, that break of gauge had no proper connection with the larger of the two great subjects under consideration, namely, that of the applicability of the mètre gauge for State lines generally. Nevertheless, it would be useful to correct some exaggerated notions of the disadvantages of the break of gauge which had been deduced from English experience. Previously, however, he was bound to make the 'amende honorable' by correcting a mistake of his own. He had been very properly taken to task by Mr. Hawkshaw for assuming 4*d.* per ton to be pretty generally considered to be the maximum representative, in cash, of the commercial ill effects of a break of gauge; for although in the report of General Strachey, Colonel Dickens, and Mr. Rendel, he found that rate given as a maximum, Mr. Hawkshaw, in his report, said that the rate per ton was variously reckoned at 4*d.*, 8*d.*, and 1*s.* Mr. Thornton acknowledged his inadvertence, and humbly apologised for it, though he would presently show it to be of no consequence, in respect to the present issue. Some persons present would not, however, be content with his crying 'peccavi' to the extent merely of confessing that, whether 4*d.* per ton was, or was not, the maximum expense incident to break of gauge, it was not in England admitted to be so. One gentleman, if he recollected rightly, declared the evils of a break of gauge to be simply infinite; another, that they could not be estimated in money; while a third demanded whether, if 4*d.* per ton—or anything like 4*d.* per ton—were their pecuniary equivalent, it was likely that the English broad-gauge companies would, for the sake of saving such an insignificant expense, have gone to the enormous expense of relaying most of their lines on the narrow gauge? Well, he was quite sure they would not. They would not have cared a jot, even though the cost per ton had been 4*s.*, or £4, for that matter, instead of 4*d.*, provided the traffic would have consented to pay that rate for translading. What really actuated the broad-gauge companies was not the expense of translading, but the impossibility of competing with the narrow-gauge companies, which had no break of gauge, and no translading to charge extra for; and to render such competition impossible, not 4*d.* per ton, but one farthing per ton would have sufficed. A farthing per ton would suffice to turn the scale in the eyes of traders, who were considering by which of two rival lines they would send their goods. But in India there was no idea of letting the two gauges come into competition. There were not to be there any standard-gauge lines and mètre-gauge lines running from the same point in the same direction. Goods brought by railway to any station, at which the break of gauge occurred, and intended to go on by railway, would have no choice but Hobson's. They must either proceed by the mètre gauge or by the standard gauge, as the case might be, or they could not go on by railway at all, for there would be but one gauge to go on by. The only question for the trader would be whether, rather than pay the extra railway charge for break of gauge, he would not send on his goods by road or river, and there could not be much doubt in which way any trader in his senses would answer that question. At any rate, the good sense of the Meeting would at once decide that the extra railway charge for translading would certainly not be so high as what the trader would have to pay for transferring his goods from a railway train to ordinary carts, or boats, or steamers.

Were there, however, no means of ascertaining with some approach to precision what the extra railway charge consequent on a break of gauge would actually be, in India? Captain Galton apparently considered that there was some mystic connection between it and the price of the goods affected, and on that ground he had contended that, instead of an amount of £850—at which, at the rate of 4*d.* per ton, Mr. Thornton had reckoned the charge for translading 51,000 tons and upwards of salt and sundries at Lahore —the amount should be at least £16,000. He really wondered that Captain Galton was not himself taken aback by his own figures. Sixteen thousand pounds sterling—merely for removing about three times that number of tons of salt from one set of trucks to another set of trucks a few yards off! It was very good natured of Captain Galton to devise such freaks of fancy, for the amusement of the Meeting; but life was too short to allow of their being seriously discussed. The Meeting could have a good laugh at them, and then he would pass on. Only if Captain Galton should interpose, to the effect that he was referring not to the mere cost of handling goods, which was the only thing Mr. Thornton was speaking of, but to the damage and injury to goods, incidental to a break of gauge, repeating, on the authority of his salt-manufacturing friend in the Midland districts, that one shilling's-worth of every thirty shillings'-worth of salt transladen was spoilt in consequence, his rejoinder would stand thus. What severer satire could possibly be passed on English railway management? On Indian railways—those at least which would belong to Government—it was to be hoped things would be better managed. Proverbially inefficient as all Government executive arrangements were, Government did not despair of being able to devise some means of getting goods transferred from one train to another train close by, without one bale or sack or ton in every thirty being spoilt or lost or plundered during the operation.

Descending, however, from these imaginative flights to the solid ground of fact, the Meeting had been told by Mr. Rendel, Consulting Engineer of the East Indian railway, that on the Nulhatti offshoot from that line the actual contract charge for translading from the broad gauge to the narrow gauge, or 'vice versâ,' was only 3*d.* per ton; and to this important piece of testimony Mr. Thornton was able to add another, equally important and unimpeachable, derived from another Indian railway—the Eastern Bengal—of which Mr. Hawkshaw was Consulting Engineer. To and from Kooshtee, the present terminus of that line on the river Ganges, a great deal of traffic was carried by a steam flotilla belonging to the company, that portion of traffic, of course, breaking bulk at Kooshtee. Now, in a report, dated in September, 1870, by Mr. Prestage, the Railway Company's agent in India, it was stated that the quantity of goods breaking bulk being taken at 145,620 tons, the mere handling of them, according to the actual rates paid at Kooshtee, would amount to 30,580 rupees, or £3,058. Dividing this sum by the tonnage, the quotient would be a minute fraction over 5*d.* per ton; and this it would be observed was for transladling, not from railway train to railway train, but from river to rail, or rail to river; obviously a much more difficult and troublesome operation. Wherefore, whatever were the extra charge for a break of gauge per ton in England, whether 4*d.*, 8*d.*, or 1*s.*, or 6*s.*, it was clear that, in taking its maximum in India to be 4*d.* per ton, just half way between 3*d.* and 5*d.*, he had, instead of understating, rather overstated it.

This, however, being assumed to be the average rate, let it be inquired what it would amount to on the whole 10,000 miles of projected State railways—and here he would interpose that these 10,000 miles were not a mere myth; he could assure Mr. Berkley he could show him projected lines which, taken together, would make up 10,000 miles.* On the 5,000 miles, almost entirely broad gauge and guaranteed, already open for traffic, the total quantity of goods of all descriptions carried in the year 1871 was, according to Mr. Danver's official report, 3,330,000 tons. That was the whole traffic of every description carried by all the guaranteed railways in India. Now no one could reasonably expect that, on the 10,000 miles of State railways, the aggregate annual traffic would for years to come amount to that, still less that it would become twice that traffic. Nevertheless, what no one could expect, he would, for the sake of argument, suppose. He would suppose that, not at some distant date, but immediately on their being all opened, the aggregate annual traffic would be not 3,330,000 tons, but 6,600,000 tons. Again, no one could expect that nearly so little as one-half of the aggregate traffic would be local traffic—that was, traffic not passing from the mètre-gauge lines—or therefore, that nearly so much as one-half would be through traffic that would have to break gauge on exchanging to or from the standard gauge. Yet, once more—what could not be expected—he would, for argument's sake, suppose,

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* *Foot-note added by* Mr. Thornton, *on the* 7*th of May*, 1873.

I am sorry to find myself, on further inquiry, obliged to admit that this was a considerable over-statement. The Indian Government did certainly in March, 1869, represent to the Secretary of State that about 10,000 miles were then wanting, in addition to the 5,000 miles already constructed or in process of construction, to provide India with a complete network of railways, but of those 10,000 miles, not more than 3,000 have as yet been actually marked out.—W. T. T.

namely, that not less than 3,300,000 tons would have to break gauge. Yet even under these almost impossible suppositions, £50,000 per annum would, at the rate of 4*d*. per ton, be the utmost expense consequent on break of gauge. But on the £10,000,000 which he had shown to be the probable saving consequent on the adoption of the mètre gauge, the interest at 5 per cent. was £500,000. On the £6,000,000 which, according to Mr. Bidder, would be saved, it would be £300,000. On Mr. Harrison's £4,000,000, it would be £200,000. Nay, even on Mr. Bruce's £2,000,000, which nobody but himself, not even Mr. Harrison, considered more than one-half the proper amount, it would be £100,000. What doubt, then, that the Indian Government were right in not sacrificing the equivalent of, at the very least, £100,000, and almost certainly £500,000, for the sake of saving an expense of only £50,000 per annum? If there were any doubt, there was one consideration that ought to remove it. The very lowest of these estimates, even Mr. Bruce's paltry £2,000,000, put out at interest, would in 4 years or 5 years accumulate to the amount requisite, at £500 per mile, for taking up and relaying, on the mètre gauge, the whole existing 5,000 miles of guaranteed lines, should the break of gauge between them and the State lines ever turn out to be a serious disadvantage. And if it would thus happen, even with Mr. Bruce's £2,000,000 how would it be with Mr. Harrison's £4,000,000, or Mr. Bidder's £6,000,000, or with Mr. Thornton's £10,000,000? Why, according as one or another of those turned out to be the nearest approximation to the real amount, the present broad-gauge lines might all be relaid on the mètre gauge, and the break of gauge be got rid of, and Government would nevertheless find itself with £2,000,000, £4,000,000, or £8,000,000 more in pocket than it would have done, if it had avoided break of gauge by making its State lines on the standard gauge.

Thus much for the general question; to which succeeded the special one, whether there were in the Punjâb any circumstances so exceptional as to render the considerations, hitherto set forth, inapplicable to that province. Upon this point, his most prominent antagonist was his ingenious friend Mr. Lee Smith, who began by intimating that he had devoted much study to the subject, and could give a good deal of information regarding it, not generally known, and who certainly did treat the Meeting to one or two novelties. Any shareholders in the East Indian railway, who happened to be present, must have pricked up their ears on being told by him that a section of 81¼ miles in length of their line, of which he had responsible charge, was constructed for £6,160 per mile; and

44 miles for exactly £5,370 per mile. Knowing, as they did but too well, that whatever their railway might have cost, they at all events had been charged for it more than £20,000 per mile, they might naturally be curious to know what had become of the odd £14,000 per mile, and they had better perhaps call upon their Engineers, or whoever else was responsible, to explain. Some others of the details entered into by Mr. Lee Smith were considerably more recondite than apposite. He blamed the Government for resolving to utilize as much as possible for railway purposes the trunk road already constructed at very great expense between Lahore and Peshawur, notwithstanding that he had recommended quite a different line, which would have left this trunk road unused and useless, and have converted its cost into so much money thrown away. Again, he blamed Government for deciding that part of the Indus Valley line should be on the right bank of the Indus, notwithstanding that he, with curious infelicity, stoutly maintained that the right bank was the wrong one. Further, he proved to demonstration that if Mr. Thornton's figures or Mr. Fowler's figures were compared, not with their own figures, but with General Strachey's figures or somebody else's figures, the comparison would not bring out the same results as if it had been made with their own figures. To show how little all this had to do with the position taken up in the Paper, it might have sufficed simply to repeat what that position was. Mr. Thornton need not, however, do even that. Most of what he might call Mr. Lee Smith's financial criticisms might be still more summarily disposed of. Within the last few days there had been received from the Government of India a despatch, in reply to one from the Secretary of State, forwarding for report certain representations of Mr. Lee Smith, to the effect that Government, by letting an anonymous Contractor, whom he knew of, make the Punjâb lines on the broad gauge instead of on the narrow gauge, would absolutely save money. The following were extracts from that despatch:—

"In regard to the real cost of changing now from the metre to the 5½ feet gauge, we have received the following report from our Consulting Engineer for State railways, which is concurred in by our other professional advisers:—

"I have carefully gone into the question of comparative cost of the two gauges, and, taking into consideration the work already done, the results are given in round numbers as follows:—

"Amount by which a railway with an unbroken gauge of 5 feet 6 inches will exceed the cost of a metre gauge line, from Kurrachee to Peshawur."

The comparison was made with both 60 lbs. rails and 40 lbs. rails; but as it was now admitted on all hands that the yet unexecuted portions of the Punjâb system must have light rails, Mr. Thornton would trouble the Meeting with only that portion of the estimate relating to the 40 lbs. rails :—

Railway.	With 60 lb. rails.	With 40 lb. rails.
	£	£
Indus Valley railway	1,021,900	531,900
Lahore to Jhelum	376,900	135,700
Jhelum to Peshawur	757,400	494,000
Total	2,156,200	1,161,600
Deduction for third rail and additional rolling-stock	620,000[1]	440,000
Net Excess	£1,536,200	721,600

" The structures with the 60 lb. rails are intended to suffice for ordinary broad-gauge engines, as well as for carriage and wagon stock; those with the 40 lb. rails are intended to suffice for broad gauge carriage and wagon stock only.

" The estimate includes the entire loss which would accrue from the abandonment of works on the lines in progress, but presumes that all rails, girders, &c., suited for the narrow gauge, can be made use of elsewhere in India.

" We believe your Grace may rely on this estimate as giving as nearly as possible, without entering upon surveys and very minute calculations, the probable cost of altering the gauge of these lines at the present time. It will be seen that the result differs entirely from that arrived at by Mr. Lee Smith, and that the figures given do not (for the reasons above explained) admit of detailed comparison."

In the Paper, the total net saving claimed for the Punjâb system was £532,823, but it had now been ascertained to be at least £720,000, or nearly £200,000 more than Mr. Thornton had reckoned upon. He

[1] " This is the estimated cost of laying a third rail on the lines between Kurrachee and Kotree, and between Lahore and Mooltan, and of providing additional rolling-stock for military emergencies. If the broad gauge were adopted with 60 lb. rails, the whole estimated sum of £620,000 would be deducted. If the rail be of 40 lbs. weight, the heavy engines of the guaranteed lines could not travel on the rails, and the portion of the deduction calculated for the engines could not be made. A reduced reduction is therefore made for that case."

might naturally be expected to be well content with so large and unexpected an addition to his original claim, but he was not so. His appetite had, he supposed, grown by being fed. The saving estimated by the Government Engineers had been reduced from £1,161,000 to £720,000 by deductions for third rails and additional rolling-stock, but the greater part of those deductions he believed he could show to be quite uncalled for. In the Paper he had contended that no additional rolling-stock would be required by reason of the mètre gauge on the Lahore-Peshawur line; since, whether the gauge were the standard gauge or the mètre gauge, to whatever quantity of rolling-stock were needed for ordinary traffic, addition would equally have to be made for extraordinary emergencies; and no one had ventured to impugn so palpable a truism. Even Mr. Lee Smith had shrunk from running his head against that post. Mr. Thornton had further contended that, on the Lahore-Mooltan line, the aggregate of rolling-stock would not need to be augmented in consequence of the creation there of a mixed gauge; because, in his opinion, to whatever extent the mètre-gauge rolling-stock was provided, the broad-gauge stock would become superfluous and might be dispensed with. But here, he confessed, he was fairly caught tripping by Mr. Harrison, who, with no more than just severity, remarked that, as the merest tyro in railway management ought to know, more rolling-stock would practically be sure to be wanted on a railway, if the traffic were divided between trains of two different gauges instead of being all despatched by vehicles of one and the same gauge. Even Mr. Thornton, who would be too much honoured by being termed a tyro, must own that he ought not to have overlooked a point so obvious, and taking shame to himself accordingly for the oversight, would now do his best to repair it. Since in the circumstances supposed, some more rolling-stock would plainly be required, let it be inquired, how much more? The Lahore-Mooltan line having, let it be supposed, become a mixed gauge, and been adequately supplied with mètre-gauge stock, the quantity of broad-gauge stock required, in addition, would of course depend upon the proportion of traffic that would be required to be despatched by broad gauge. Now the traffic that must necessarily, or rather that could preferably, be so sent, was plainly only so much as having either originated in, or being destined for, places eastward of Lahore would have to pass through Lahore. For all the rest of the traffic, for all, that both originated in, and was destined for, places between Lahore and Kurrachee, the mètre gauge would serve just as well, and for much of it very much better than the broad gauge—just as well for all traffic both originating in, and stopping at, places north of Mooltan; very much better for all traffic either originating in, or bound for, places south of Mooltan, and which if sent by the broad gauge would have to break gauge at Mooltan. Very well then, the traffic requiring to be sent by broad gauge would be such only as required to pass through Lahore. But, although there had for some time been continuous broad-gauge railway communication between Mooltan and the whole region eastward of Lahore, the portion of the annual goods traffic of the Lahore-Mooltan section passing in either direction through Lahore was at present only 12,930 tons; neither, indeed, could it be estimated at nearly so much, except upon the highly improbable supposition that the whole of the existing traffic between the Punjâb and the territory to the eastward was carried by rail, and none of it by river or common road. Taking it, however, at 12,930 tons, that was the whole amount of traffic on the Lahore-Mooltan line, for which, in order to save it from the necessity of breaking gauge, it would be necessary to provide standard-gauge rolling-stock. But 12,930 tons distributed over 313 working days gave an average of only 41 tons a day, or about 4 standard-gauge-wagon loads. Of the whole existing quantity of such stock, therefore, only 6 wagons, or say at the utmost 12 wagons, together with proportionate engine power, would need to be reserved; all the rest might be replaced with mètre-gauge stock, and be disposed of by sale to some other broad-gauge railways; the guaranteeing Government which would have to bear any loss, consequent on such sale, being to a great extent, if not completely, indemnified by the corresponding gain obtained by the purchasing railway.

After all, then, it seemed that, though theoretically wrong with regard to the Lahore-Mooltan section, he was practically all but, and should have been quite, right, if, instead of saying that neither for it, nor for the Lahore-Peshawur line, need one penny of expense be incurred for extra rolling-stock, he had said that some £5,000 or £6,000 would be the utmost expense needful on that account. All, therefore, beyond this mere trifle that the Government Engineers had deducted from the first total of savings in their recent estimate, ought now to be restored, in order to bring back that total to its proper amount. But that was not all. If, when, by the laying of a third rail, the Lahore-Mooltan line had become mixed gauge, there would be next to no traffic to travel upon the broad gauge, what use was there in laying a third rail? Why not, instead, take up the permanent way and relay it on the mètre gauge, thereby saving the difference of cost between the two operations, which he had seen estimated somewhere at £783 per mile or at £167,462 for 214 miles, and obtaining the latter sum as a further additional saving? Among other recommendations of this plan, was that they should thereby get rid of what Mr. Lee Smith called the "third leg to a pair of breeches." The double gauge proposed by Mr. Fowler for the section between Lahore and Mooltan ought really to have been likened to a pair of breeches with two legs. The problem, according to Mr. Lee Smith, would be to divide at Mooltan, between the broad gauge and the narrow gauge, the goods brought thither from the southward, by a single narrow-gauge line; and this problem he pronounced insoluble by any ordinary station-master. It did not occur to him that the problem might have been solved beforehand by the station-masters at places south of Mooltan. He took it for granted that the station-masters would be too stupid to think of putting goods intended to go beyond Lahore into one set of wagons, and the goods intended to stop short of Lahore into another set. Truly, if the generality of station-masters, on the existing Indian railways, were no greater geniuses than those with whom he seemed to have come in contact, it was perhaps a good thing that their traffic had hitherto been so much less than was originally hoped for. With anything like the English average of traffic they would apparently have been at their wits' end.

To return—enough had been said to show that, so far from half a million, or three-quarters of a million pounds sterling being an over-statement, the real saving consequent on the adoption of the mètre gauge for the whole Punjâb system was not unlikely to be a good deal over a million pounds sterling, nearer perhaps to the figures of General Strachey than to those of any one else. Little, then, remained but to determine whether, or how far, this pecuniary saving would be counterbalanced by the evils attendant on a break of gauge. Here, at the outset, Mr. Thornton must take leave to remark that much of what had been said by the Astronomer-Royal, by Mr. Allport, and others as to the commercial evils of the break of gauge, although perhaps perfectly just, was also perfectly irrelevant. Neither, Mr. Thornton must own, however convincing it might have seemed to others, was he always convinced by it. When, for instance, Mr. Allport imagined the case of a narrow-gauge truck load of 5 tons or 6 tons of goods having to be transferred to a broad-gauge truck, capable of carrying 10 tons, it occurred to Mr. Thornton that for the waste of space and increase of dead weight that would then take place, there might not impossibly be full compensation when, the circumstances being reversed, the freight of an only half filled broad-gauge truck was transferred to a narrow-gauge truck, which it would completely fill. Again, when Mr. Allport spoke of eight millions or nine millions of tons of coal being annually carried on the English Midland line, Mr. Thornton did not fail tacitly to admit that if there were the slightest chance of that quantity of coal, or salt, or anything else, having to break gauge at Lahore, it would be well worth while to spend not one million, but two millions, or three millions extra, in order to prevent the indescribable block thereupon inevitable. But at Lahore, at which place alone, if the section between it and Mooltan was relaid, as he had suggested, there would be a break of gauge, there would, as could be shown by appeal to indisputable facts, be no question of eight million tons, or nine million tons, but only, at the very outside, of some sixty thousand tons. He found, indeed, with reference to what he had said on that point, that a deservedly-esteemed journal, "Allen's Indian Mail," remarked that he made no allowance for the certain growth of traffic from the Punjâb to various parts of India as new lines of railway were opened out. But he begged to say that, so far from making no allowance, he allowed very nearly a four-fold increase on that account. He found, speaking of the country between Lahore and Peshawur, the total traffic passing annually through Lahore from either east to west, or west to east, to be only 526 tons, exclusive of salt, or 13,526 tons, inclusive of salt; and he assumed it, immediately after the completion of the railways, to spring up at once to 51,052 tons, inclusive of salt. He did not really believe it would become anything of the kind. That continuous railway communication from Peshawur to Kurrachee would immensely develop both the internal traffic of the Punjâb, and also its external trade through Kurrachee, and with the country west of the Indus, he had no manner of doubt, and he heartily congratulated Mr. Andrew on the brilliant future in store for those portions of that continuous line of which he was Chairman, when his sections, relaid on the mètre gauge at the charge of Government, and, therefore, with their working expenses materially reduced, should at length receive free, gratis, and for nothing, abundant accessions of commerce, brought to them from both directions by the no-longer missing link. Whatever other people might think or feel, the shareholders in Mr. Andrew's Company, at all events, would have reason to congratulate themselves that sections sure to be unremunerative themselves, but calculated to render the Company's sections remunerative, would have been made at the cost, not of the Company but of the public. But that very little, if any, of this new trade would pass through

Lahore was as certain as that the trade itself would arise. Why should it? Of what description was the existing through traffic at Lahore? On examining the statistical tables, to which he had referred, it would be found that of its paltry total of 526 tons, exclusive of salt, passing towards Peshawur, or ' vice versâ,' a good deal more than one-half consisted of imports from Calcutta to Peshawur, Rawal Pindi, and Dera Ismail Khan, no doubt chiefly European supplies for the use of the European inhabitants of those outposts. But of mutual interchange of indigenous products between the territories east and west of the rivers Ravee and Sutlej there was almost nothing, nor so long as the industry of the territories remained chiefly agricultural was there likely to be any change; for to send farm produce of almost any kind, in either direction, from one side to the other, would be like sending coals to Newcastle. Salt had hitherto been the only article interchanged to any extent, and even of that the interchange was more likely to diminish, than to increase when the State railways in progress should freely circulate the salt of the Jhelum mines throughout the Punjâb, and the salt of the Sambhur Lake throughout Rajpootana.

It thus turned out that, on the supposition of there continuing to be broad-gauge communication from Mooltan through Lahore, he was fully warranted in taking £850 per annum to be the full pecuniary equivalent of the commercial evils of the break of gauge, although if, as he had suggested, the Lahore-Mooltan section was made on the metre gauge, 12,930 fourpences, or £210 would have to be added, raising the £850 per annum to £1,060 per annum. In regard to the strategic evils, he had had the satisfaction of hearing all he said borne out, and more than borne out, by that highest of all authorities, Lord Lawrence, who had shown the Meeting that, so far as military movements were concerned, it would practically matter little if there were three breaks of gauge, or four breaks of gauge. In fact, however, there need be but one break of gauge, namely, at Lahore. Now, no doubt, this single break might suffice to present an insuperable obstacle to the rapid passage of troops and munitions of war through Lahore. No doubt if, as supposed by Mr. Brunlees, an army with its baggage, commissariat, ammunition, and artillery accompaniments, was to be brought thither by the broad gauge with the view of being passed on forthwith by the narrow gauge, the confusion would be indescribable—scarcely imaginable even by those who had visited Waterloo station on the day of a Volunteer review at Wimbledon. And so similarly of Mr. Allport's hypothesis of 20,000 soldiers, or 30,000 soldiers, with horses and equipments, having to be rapidly shifted from one set of trucks to another. If there were the smallest chance of such a contingency it would be penny wisdom indeed to suffer a break of gauge at Lahore, for the sake of almost any pecuniary saving. But his contention was that no such contingency could, by any possibility, occur. Although there would be a break of gauge at Lahore, neither troops, nor munitions of war, would ever have occasion to break gauge. Lahore being, in case of an invasion, made—as he was confirmed by Lord Lawrence in assuming it would be made—the basis of operations, and depôts and magazines of all sorts being established there, it would become the starting point for all troops and munitions proceeding westward or southward into the interior of the Punjâb; while from Lahore, westward or southward, there would everywhere be uniformity of gauge. His argument, in short, was, that all forward military movements would commence in advance of the break of gauge; so that, in regard to them, there would be no break of gauge. Now this argument was surely decisive, if it could be maintained, and against it not a syllable had been said by any one but Captain Galton; and what did he say? why, that a railway enabled an army to dispense with the formation of large magazines in its neighbourhood, for that it enabled them to draw supplies from almost unlimited distances; and Captain Galton proceeded to speak with admiration of the excellent arrangement for that purpose made by the Germans during the late war with France. But did Captain Galton really mean that the Germans had no magazines at Mayence and Coblentz, and the rest of their nearest line of fortresses, and that, whenever a gun was dismounted in the trenches before Metz or Paris, they had to wait until another could be brought up from Magdeburg or Berlin? If so, no wonder the Germans could not force their way into Metz or Paris. Greater than ever was the wonder that the Parisians, or, at any rate, the Metzians, did not break through the German lines. It would, he feared, go ill with the Government if a British general, in the field near the Bolan or the Khyber Pass, had no depôts, at least as near as Lahore, to draw upon, but, whenever guns or gunpowder failed, he had to send for them to Ishapore or Kirkee. Captain Galton further pointed out, that forward movements were not the only ones to be provided for, but that return movements likewise, and particularly those of the wounded, were to be thought of; but time pressed, and Mr. Thornton would therefore pass very lightly over what Captain Galton had said on that head. It really did not matter whether it was true or not that four wounded men and a nurse might be placed in a broad-gauge wagon, while in a narrow-gauge wagon there would be room for only two men and a nurse. All the nursing in the world would avail little for whole trains full of sorely-wounded men, incapable—to use Captain Galton's words—of moving hand or foot, who, after being brought from Peshawur or Dadur by rail to Lahore, were not allowed to alight there, but were sent on without stopping to hospitals at an unlimited distance. Graveyards would serve as resting-places for most of the unfortunates so thoughtlessly treated, long before they reached those far-away hospitals.

There were but two points more to which it was necessary to allude. One was the capacity of the mètre-gauge vehicles to carry the field artillery that would be needed for a campaign on the frontier; the other was the numerical sufficiency, on extraordinary emergencies, of the rolling-stock of the Punjâb railway system, cut off, as it would be, from borrowing from the broad-gauge railways of the rest of India. With regard to the first, Major Williams, of the Royal Engineers, Assistant-Secretary to the Government of India, in the Railway Department, had intended to speak, and was prepared to prove the case of Government, by detailed measurements and calculations. Major Williams was, however, he was grieved to say, prevented by what had been a dangerous illness from attending the discussion; and in his absence Mr. Thornton could only suggest that, whosoever had any doubts on the subject, should accept Mr. Rendel's challenge, and, going to Lancaster, should get his doubts removed by personal inspection of the mètre-gauge carriages, which were there awaiting shipment to India. Gentlemen might also do well to recollect what had been said by Mr. Douglas Fox of the width to which narrow-gauge vehicles might safely be extended, on the Canadian narrow-gauge stock, which were identical in width with the Indian broad-gauge stock, and it would be seen how, if it were deemed desirable, stock of the same width might be adopted on the narrow gauge of the Punjâb.

With regard to the second point, Mr. Thornton repeated that, even though the Punjâb lines were of the same gauge as the generality of the existing Indian lines, the heavy engines of the latter could not travel on the light rails of the former, without soon destroying them. To this Mr. Bruce, indeed, replied that they could do so, provided only they traveled slowly enough. But Mr. Bruce forgot that the sole object in borrowing stock on military emergencies would be that of getting troops and stores moved on with extra rapidity, an object which would scarcely be answered by placing them in trains hauled by engines forbidden to travel except at a snail's pace.

The remarks in the Paper upon the needlessness of borrowing rolling-stock from other railways, even if such borrowing were possible, had been curiously twisted, by Mr. Lee Smith, into an admission on Mr. Thornton's part that the rolling-stock of the Punjâb would be insufficient, unless it were supplemented by borrowing; and Mr. Lee Smith had proceeded to fortify this interpretation of Mr. Thornton's language by independent considerations. Mr. Lee Smith throughout his speech, although exhibiting great imaginative and reasoning power, had betrayed at the same time a somewhat defective memory. He was continually fancying Mr. Thornton to have said things which it had never occurred to any one, but to Mr. Lee Smith, to say, and had then gone on to prove those things to be very ridiculous, forgetting that it was he alone who had put them into Mr. Thornton's mouth, and that therefore it was Mr. Lee Smith's nonsense, not Mr. Thornton's nonsense, that Mr. Lee Smith was refuting. He would have it, and would not be set right, that, when Mr. Thornton said that with the quantity of rolling-stock proposed for the whole Punjâb system, 12,000 men might be sent in a week from Lahore to Peshawur, he had further said that this might be done with only 2 trains a day. Mr. Lee Smith would have it that, if Mr. Thornton had not said this, he must, at any rate, have meant it; for that Mr. Lee Smith could prove that the whole rolling-stock would not suffice for more than two trains. Mr. Lee Smith's proofs were given thus:—12 trains a day, of 30 mètre-gauge vehicles each, or 360 vehicles altogether, would be required for the transport of 1,000 fully equipped men per day, or for 7,000 men per week. 11,000 men would therefore require 560 vehicles. Now, the whole length of rail from Peshawur to Kurrachee being in round numbers 1,100 miles, its aggregate rolling-stock, at the rate assumed by Mr. Thornton and understood to be proposed by Government, namely, 1 engine and 30 vehicles per 13 miles, would be 84 engines and 2,538 vehicles, which latter figure, divided by 30 vehicles—Mr. Lee Smith's allowance of vehicles for 1 train—would yield a quotient of what? According to Cocker, of about 84 trains—according to Mr. Lee Smith, of only 2 trains. What was to be thought of such arithmetic? What but that a man might be a responsible Engineer, and yet be no great adept at ciphering? Mr. Lee Smith's own sums, if he had done them rightly, must have satisfied him that the amount of rolling-stock proposed for the Punjâb would by itself amply suffice for all conceivable contingencies, and that there would never be any occasion to borrow. But, beside this, let it be recollected that, if it should by any possibility ever become desirable for the Punjâb railways to borrow, they could not, if made on the broad gauge, borrow to any useful purpose, because the heavy stock of the adjoining broad-gauge lines could not be safely employed upon their light rails. If the almost impossible necessity of borrowing really deserved to be provided for, that might best be done by making the Punjâb lines on the narrow gauge, as was proposed, and then connecting them with the narrow-gauge lines of Rajpootana. And to this end it would by no means be necessary, as Mr. Lee Smith supposed, according to his habit of first fathering an absurd notion on his opponents, and then denouncing its absurdity, to start a junction line from Ajmere, and to carry it through a howling wilderness to Bukkur, an inventive genius less fertile than Mr. Lee Smith's might have suggested that, merely for the purpose of rendering the narrow-gauge rolling-stock of the Punjâb and Rajpootana railways interchangeable, it might be sufficient to lay a third rail on the section of broad gauge already existing between Delhi and Lahore.

Here Mr. Thornton would conclude, with many thanks for the patience with which the Meeting had listened to him, and many apologies for having trespassed so long upon their patience. What had already been said would probably be accepted as a sufficient pledge that a good deal more might—if necessary—be said in support of the points which he had endeavoured to establish, namely, that a very considerable saving would result from the adoption of the mètre gauge for the Punjâb railways, and that to counterbalance that advantage there would be next to no commercial and absolutely no strategic disadvantages. He did not flatter himself that many converts had been made to views in great part so novel. No doubt the old saw about "those who were convinced against their will" being "of the same opinion still" applied very well to each of the two parties into which the Meeting was very unequally, he feared, divided. The opinions of most of those who were present were most likely just the same as when they entered the room. Still, how much soever they might differ in other respects, they had, he trusted, at least one point of concord. He did trust that Lord Mayo would no longer be suspected of having, when adopting his narrow-gauge policy, taken up a mere idle crotchet and childish whim. He did trust that such injustice would no longer be done to the memory of so noble a member of the noble army of martyrs to public duty. In a private letter which Mr. Thornton had seen, written only two or three days before his assassination, Lord Mayo spoke of that policy as one which it would always be a pride to him to look back upon; and he might at least be credited with not having resolved upon it without anxious deliberation, or without carefully weighing the arguments on both sides. There was yet another point on which the Meeting would probably be quite unanimous. Since the discussion had begun, before the Institution, the same question had been discussed in the House of Commons, and the Prime Minister had promised that the Government of India should be urged to reconsider the subject by the fresh lights then thrown upon it. In whatever else they might differ, they would probably all agree that it would greatly assist the Government of India in coming to, or, as he should himself prefer saying, in adhering to a right decision, if it were furnished not only with the Minutes of the House of Commons' debate, but also with those of the Discussion which was now concluding.

Mr. Hawksley, President, said, he would very briefly occupy the attention of the Meeting. The discussion upon the Paper had extended over seven evenings. It had been exceedingly interesting, and he believed it had elicited opinions on both sides which were well worthy of the consideration of Engineers occupied in railway construction in all parts of the world. But with regard to this special case of India he imagined some of the most material parts of the subject had not received all that attention which they deserved; and in particular he thought that the Author had directed their attention to the subject rather too much from the economical aspect. There were other points of view which were of greater importance. India was a conquered country, and was held at that moment by force of arms. It was therefore more necessary to view the subject under the strategic aspect than it was to view it under the economical aspect. There were great nations —much greater than the United Kingdom—who, if they had not at the present moment designs upon the Eastern possessions of Great Britain, might, and probably would in a few years entertain designs upon a territory which would become even more valuable to them than it was to us. Now, it occurred to him that the whole of that part of the frontier of India which was accessible to attack should be duly protected, and that it did not signify in the least whether Great Britain spent, or whether India spent ten millions more or less in preventing the incursions of an enemy. It was clear that in a country which was eighteen times the size of the British isles, and in which there were six times the population of the British isles, and where there was a population which held—or at any time, by intrigue from without, or exasperation from within, might become induced to hold—their British rulers in disfavour, it was the duty of those rulers to protect themselves, not only in the front but also in the rear. The Government might have an enemy invading India at the frontier, and it was quite possible that it might have a mutiny or an insurrection behind. Under those circumstances, suppose the great main lines of the country to be laid upon what he might call the break of gauge system: suppose that the army sent to the frontier should be overpowered, and suppose it should have troubles behind, and suppose it should be obliged to effect a retreat—what was to be done? When the troops came to a narrow-gauge line—a line which could not convey them, especially in the hurry of retreat, —they must get away their munitions, their stores, and their wounded, and those were to be got hastily on to that narrow-gauge line, and where were they then to come to? They were to come to a break of gauge; and then, what were they to do, with an enemy advancing rapidly upon them, and the country, on reasonable possibility, in the hands of a rebellious population? They would have no suitable carriages at hand, and they could not obtain them from a distant part of the country, and if they did come, there would be all the difficulties and delays of the transfer. Then what must happen? Why, unless there was at each change of gauge a sort of Metz or Strasburg in which the army could be received and where it could defend itself, as a matter of course the army must be lost. Now he would ask whether that was a proper state of affairs? He ventured to think, as an Englishman, it was not a proper state of affairs; and therefore he said that, irrespective of economical considerations, they ought to have all the main lines of the country made upon one gauge, and that gauge competent to all the exigencies of a possibly untoward occasion. It was, however, quite possible that in a great country like India, and especially in the naturally well protected parts, where the population was sparse, a gauge narrower than the 5 ft. 6 in. gauge might suffice for the purposes of the traffic, although it would still be subject to the inconveniences attendant upon a break of gauge at all its junctions with the main lines—and here he would observe, that the whole of India was not at the present time less densely populated than England was at the commencement of the reign of George I., and that was only a century ago, the number of acres to the people being indeed almost the same. Let them then consider whether, had railways been then known, they would not have been useful in England at that period of our history, and what would at that period have been the proper gauge? He ventured to think the mètre gauge would even then have been found wholly insufficient. What, he would ask, was to be gained by making or substituting those narrow gauges for the main lines of India? Why, it was admitted that the main lines had not cost more—and it was a large sum—than £15,000 per mile, and it was also admitted that, under favourable circumstances, they could be now extended at something like £6,000 per mile. Suppose, then, the future main lines could be made at an average cost of £10,000 per mile, and let them also suppose, and they knew that to be about the truth, that the difference of cost between the narrow-gauge construction and the ordinary construction was about 10 per cent. The saving would be, at the most, £1,000 per mile, and if 10,000 miles were wanted, the total saving upon a broad-gauge expenditure of £100,000,000 would be only £10,000,000. But there were 200,000,000 of people, and so it would cost those 200,000,000 of natives just 1*s*. per head to find the £10,000,000, and the taxation would consequently be $\frac{1}{20}$*s*. per head per annum. He would ask them whether that was an important amount when placed in comparison with the safety of an immense empire and of the national interests, which would be involved largely in the decision the Indian Government might make with regard to the question now before the world. For his own part, whilst admitting that he thought the Indian gauge of 5 ft. 6 in. had been a mistake, and that it was an unnecessarily wide gauge, in so far as it exceeded in width the better established gauge of 4 ft. 8½ in., he should much regret to see another gauge introduced into the main-line extensions in substitution for it.

With these few observations he closed the discussion, and would now pass to another and very different subject. He was directed by the Council to address a serious word to the members of the Institution upon an irregularity which had recently crept into the discussions. A habit had been acquired of reading their speeches, instead of delivering them extemporaneously with that natural emphasis which addressed itself as well to the heart as to the ear. The Council hoped in future that the practice of reading speeches would be abandoned.

In conclusion, he had only to add he was quite sure the Meeting would feel much pleasure at having the opportunity of according to Mr. Thornton their very best thanks, as an official of the Government—though he did not submit the Paper to the Institution, or address them officially—yet as an official of the Government—for having afforded them the opportunity of discussing a most interesting and a most important subject.

[APPENDIX.

APPENDIX.

CONTENTS.

I.—East India Railways.—Return to an Address of the Honourable The House of Commons, dated 11 March, 1873;—for,

"COPIES of Correspondence between the Government of India and Court of Directors, relating to the present Gauge of Five Feet Six Inches of the Indian Railways:"

"And, of the Minutes of Lord Dalhousie and the Reports of the Consulting Engineers on the subject of the Gauge."

India Office, 13 *March*, 1873.

W. T. Thornton, Secretary, Public Works Department.

Extract Financial Letter from the Court of Directors of the East India Company to the Government of India, No. 27, dated 14th November, 1849.

1. Agreeably to the intimation conveyed to you in our letter of the 25th April last, No. 9, we now forward in the packet the deed of contract, in duplicate, between the East India Company and the East Indian Railway Company for the construction of an experimental line of railway from Calcutta towards the Upper Provinces of India. We forward likewise a copy of a deed of contract between the East India Company and the Great Indian Peninsula Railway Company for the construction of an experimental line of railway from Bombay to, or near to, Callian, with a view to its extension to the Malsej Ghaut.

2. These deeds are based upon the "terms and conditions" of which you have been already advised, and which have been accepted by the railway companies.

3. Although these deeds are so comprehensive, and appear so fully to meet the objects in view, yet, that you may the better comprehend the precise motives which have actuated both parties during the negotiations with respect to the terms of these contracts, and that you may thereby the more clearly understand their various provisions, we think that it may save much trouble in future if we now enter into a detailed explanation of each of their conditions. It is, however, highly satisfactory to know that the nobleman who is now at the head of your Government has already given much attention to railway subjects, and we anticipate that

great benefit will result in the course of your deliberations from his Lordship's experience.

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13. With respect to the weight of rails and the gauge of line to be employed on these railways, we are disposed to recommend those used by the North Western Company here, namely, a gauge of 4 ft. 8½ in., and a weight of rails of 84 lbs. to the yard, as combining the greatest utility and economy.

Extract Railway Despatch from the Government of India to the Court of Directors of the East India Company, dated 2nd August, 1850, No. 1.

Paragraph 5. The question regarding the breadth of gauge, and the views expressed by his Lordship[1] on that subject, will doubtless receive your Honourable Court's attentive consideration.

Extract Report by Mr. W. Simms, C.E., Consulting Engineer to the Government of India, dated 29th April, 1850.

Paragraph 29. It is highly desirable in a country like India, where the railway system is now for the first time being introduced, and which will ultimately extend throughout the land, that one uniform standard of gauge should be adopted, and in no case to be departed from, so that whenever the various lines now and hereafter to be constructed shall meet and unite, as they assuredly will do, the facilities for transport, which is the great principle of railway practice, may experience neither check nor inconvenience.

30. The question therefore arises, what width is the most desirable to adopt as the standard of gauge. The Honourable Court of Directors in their Despatch of 14th November, 1849, paragraph 13, have expressed themselves as "disposed to recommend" (but did not order) the adoption of that known in England as the narrow gauge, namely, 4 ft. 8½ in.; but, with all due respect to the recommendation so given, I beg to state that in my judgment a wider gauge would be preferable for this country, and I would recommend the adoption of 5 ft. 6 in., or thereabouts, as I am not disposed to contend about an inch or two more or less, as I consider that immaterial.

31. After the labours of the Gauge Commissioners, and the several Parliamentary investigations on the subject of the width

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[1] The Earl of Dalhousie.

of the gauge, the results of which are before the world, it would be waste of time to enter upon the discussion in this place.

32. The wider gauge of 5 ft. 6 in., which I would recommend for adoption (as the Court of Directors have not definitely settled the question), will give 9½ inches more space for the arrangement of the several parts of the working gear of the locomotive engines, and this additional space will be more needed in India than in Europe, not only on account of machinery itself, but it would lower the centre of gravity of both the engines and carriages, the result of which would be to lessen their lateral oscillation, and render the motion more easy and pleasant, and at the same time diminish the wear and tear.

33. The lowering of the centre of gravity consequent on the adoption of the wider gauge appears to me of great importance, for another reason, namely, the fearful storms of wind so frequent in certain seasons of the year, and I think it very probable that in one severe north-western, not to mention such hurricanes as that of 1842, the additional 9½ inches of lease might make all the difference between the safety and destruction of the trains; and one such accident, attended as it doubtless would be with great loss of life, would, probably, retard the progress of the railway system in this country very considerably.

34. The additional outlay of capital attendant upon the adoption of a 5 ft. 6 in. gauge above that of 4 ft. 8½ in. in the first instance, would be but trifling in comparison with what appear to me its more decided advantages.

35. The width of the gauge here recommended was the one I selected in my own mind soon after my arrival in India in 1845, and my subsequent experience of the country has confirmed my early views on this point. It was the width I then named (as the one I intended to recommend for adoption when the proper time arrived for so doing) to the Managing Director of the East Indian Railway Company, and by him subsequently named as the intended gauge in his communications with his company.

Extract Minute by the Earl of Dalhousie, Governor-General of India, dated 4th July, 1850.

32. The Court of Directors have recommended, at the same time, the use of the narrow gauge of 4 ft. 8½ in. for the railway about to be constructed. Although the letter of the Court recommends, but leaves to the Government of India to determine as to the gauge which should be adopted on this occasion, I consider the

question to be one of such moment as to deserve a careful consideration and an authoritative and conclusive decision by the highest authority connected with the Indian Empire, who alone can have access to that full information and extended experience which would make such a decision really and satisfactorily conclusive.

33. The British Legislature fell unconsciously, and perhaps unavoidably, into the mischievous error of permitting the introduction of two gauges into the United Kingdom. The numerous and grievous evils which arose from that permission are well known, and will long be felt throughout all England. The Government of India has it in its power, and no doubt will carefully provide, that however widely the railway system may be extended in this Empire in the time to come, these great evils shall be averted, and that uniformity of gauge shall be rigidly enforced from the first. But I conceive that the Government should do more than this, and that now, at the very outset of railway works, it should not only determine that any uniform gauge shall be established in India, but that such uniform gauge shall be the one which science and experience may unite in selecting as the best.

34. At one time this question was much before me, and although I should not myself attempt to offer an opinion on so vexed a question, yet I may venture to form one on the recorded views of men competent in every way to judge. The evidence which was given before the Gauge Commissioners in 1846, and the evidence which has been given from time to time before the Committees of Parliament, backed as it has been by very high authority abroad, is, I venture to think, sufficient to show that the narrow gauge of 4 ft. 8½ in. (a measurement adopted originally at hap-hazard and from the accident of local circumstances) is not the best gauge for the general purposes of a railway, and that something intermediate between the narrow gauge of 4 ft. 8½ in. and the broad gauge of 7 ft. will give greater advantages than belong to the former, and will substantially command all the benefits which are secured by the latter.

35. The circumstances which have been brought forward by Mr. Simms in his report, applicable especially to this country, strengthen the reluctance which I feel to introduce the 4 ft. 8½ in. gauge into India, without a very deliberate reconsideration of the question, with reference to India, under the direction of the Honourable Court by the Board of the East Indian Railway Company. I should not have felt satisfied that I had done my duty if

I had not brought this question pointedly under the consideration of the court, requesting them formally and finally to determine whether a wider gauge than the 4 ft. 8½ in. ought not to be established in India, and whether the gauge of 6 ft., which was recommended by engineers of eminence in England, and which was preferred also, if I recollect rightly, by M. de Pambour, should not be introduced on the experimental line in Bengal, and at the same time on the line which is in course of construction at Bombay.

EXTRACT FINANCIAL DESPATCH from the Court of Directors of the East India Company to the Government of India, No. 46, dated 4th December, 1850.

Paragraph 9. With respect to the gauge, we concur in the opinion that a wider gauge than 4 ft. 8½ in. ought to be established in India, and we are disposed to think that the gauge of 5 ft. 6 in., as recommended to you by Mr. Simms, is most suitable. This decision will be communicated to the respective railway boards in this country.

EXTRACT RAILWAY DESPATCH from the Government of India to the Court of Directors of the East India Company, dated 7th March, 1851, No. 3.

3. Your Honourable Court have authorized the extent of the Indian gauge to be 5 ft. 6 in., as recommended by Mr. Simms. Major Kennedy thinks that the breadth of 6 ft., recommended by the Governor-General, would be preferable.

EXTRACT LETTER from Major J. P. Kennedy to the Secretary to the Government of India, No. 30, dated 27th February, 1851.

Paragraph 15. It is with the greatest possible satisfaction I have learned that the Honourable Court have sanctioned the enlargement of the general Indian gauge from 4 ft. 8½ in. to 5 ft. 6 in., and I trust I may be excused in proposing the still further enlargement of the gauge to six feet, as recommended by the Most Noble the Marquis of Dalhousie. If the Honourable Court will permit the reconsideration of this very important question, and allow me, in concert with any one or more professional men whom they may select, to offer them a report on the subject, I think that such a report may be submitted within a very few weeks after my arrival in England, next April. This could cause no inconvenience or delay whatever, either as regards the works in progress in Bombay or in Bengal, and it cannot fail of being satisfactory to the Honourable Court to be furnished with such a document in reference to a most important and disputed question which has not yet received that professional investigation that it merits as regards Indian interests. It is a question that can only now be considered with profit, as, if any error be introduced, it will be beyond the reach of future remedy.

Extract Minute by the Earl of Dalhousie, Governor-General of India, dated 11th April, 1851.

2. It does not appear, from the Despatch of the Honourable Court, whether their determination to fix the gauge at 5 ft. 6 in. was the result of any deliberate inquiry, or whether the figure was merely indicated as a mean between the extremes of the present narrow gauge, and that which I took the liberty to suggest. If the Honourable Court have fixed upon 5 ft. 6 in. for the Indian gauge on high recognised authority, and adhere to it, of course the Government has only to obey. But if this is not the case, the Court will pardon the importunity which, for their own present and future interests, urges them to take other counsel before they issue a peremptory mandate on this important point.

3. I know of old that particular figures have been fixed upon originally for a gauge, and for others proposed in substitution of it, without the author of the proposal being able to give any reason whatever for selecting the particular dimensions he had specified. The original narrow gauge of 4 ft. $8\frac{1}{2}$ in. was adopted for no other reason than because it happened to be the width of the colliery tramway on which locomotive power was first tried. When a general alteration was proposed, I recollect it being said that the principle on which one gentleman proceeded was to take all the different gauges, strike the average, and propose the figure that resulted as the best universal gauge. But I think that many good reasons *were* formerly given for the superiority of a 6 ft. over the broad and narrow gauges, and I feel confident that many more could be given why that gauge should be selected for India, in preference to either of the original gauges, as to the one now suggested by the Honourable Court.

4. At all events, if formal inquiry has not been entered into, I earnestly request the Honourable Court to permit the question to be so far reconsidered as to receive such reports and evidence on

the subject as are suggested by Major Kennedy in the 15th paragraph of his present report. If this is not in accordance with the Resolution of the Honourable Court, I shall much regret it; for I think that those who come after us will see cause to lament that the originators of this great system in the East did not profit so much as they might have done by the errors of their predecessors in Europe.

Extract Financial Despatch from the Court of Directors of the East India Company to the Government of India, No. 45, dated 20th August, 1851.

Paragraph 7. With respect to the question of gauge, to which you have again adverted, our decision in favour of the 5 ft. 6 in. gauge was arrived at, after a very careful consideration of the subject, and with the best opinions which we could obtain. That decision having been communicated to the Railway Companies, who have entered into contracts for the execution of works and for the provision of materials on the presumption that it is final, it would lead to much inconvenience and expense, if any alteration were now permitted.

II.—Report of Mr. C. B. Vignoles, F.R.S., Past-President Inst. C.E. (dated September 22nd, 1842).

Preliminary Note.—The following report was drawn up between the early part of August and the latter end of September, 1842, at the request of several influential gentlemen connected with the old East India Company, who were considering the possibility of improving the communication with China across the Indian Peninsula, in connection with the steam-boat routes then recently introduced. It was received at the East India House towards the close of November, 1842,[1] and was the first document put on record relative to railways in India.

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[1] Letter from the Secretary of the East India Company to Charles Vignoles, Esq.

Sir, *East India House, November 24th*, 1842.

Your letter of the 14th inst. enclosing a Statement and Manuscript Report on Railways in India, for presentation to the Court of Directors of the East India Company, has been duly received, and I am commanded by the Court to return you their thanks for these communications.

I am, Sir,
Your most obedient humble Servant,
(Signed) James C. Melvill,
Secretary.

It must be taken into consideration that most of the arguments in support of railways, which may now appear superfluous, were adduced more than thirty years ago, when numerous questions, since satisfactorily solved, were considered doubtful by the great body of capitalists; and that it was still in embryo whether railways for India should be undertaken at all, and if so, whether by the Imperial Government, by the then East India Company, or by private enterprise. Its Author, however, believes that the principles laid down are applicable to all times and to all countries.

C. B. V.

HINDOSTANEE RAILWAY.

1. A few years since, and, perhaps, up to the present time, the mere suggestion of establishing railway communication to any extent in India would have been considered a visionary idea; and it must be admitted that it is only those deeply interested socially, commercially, or politically in that extensive region, well studied in its hitherto unaided and undeveloped capabilities, and sensible of the rapid though silent progress of events, who can fully appreciate the importance, judge of the great results, and admit the probability of success in so vast an undertaking.

2. In proceeding to attempt a statement on such a subject, it cannot be disguised that there are numerous difficulties to be surmounted, no few prejudices to be overcome, many explanations to be made; and labouring under a sense of the weighty objections of all kinds which may be raised, *in limine*, to entertain the project at all, even in hypothetical discussion, it requires full assurance and well founded conviction existing in the mind to enable this subject to be followed up with energy, the circumstances to be discreetly considered, and the case to be distinctly and calmly discussed.

3. But when a retrospect is cast over what had to be encountered scarcely five years since, when it was proposed to establish steam

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Letter from the Hydrographer of the East India Company to Charles Vignoles, Esq.

My dear Sir, 9 *Castle Street, Holborn, October 27th*, 1842.

I return your very interesting report, and do not see anything to be improved in the Geographical part. I am much obliged to you for the perusal of it.

Yours very truly,
(Signed) J. Walker.

communication with India through the Red Sea by a regular monthly post, and knowing and appreciating the advantages from its creation and continuance, it is felt that this collateral question of a railway will soon reduce itself to definable limits of expense, direction, and returns.

4. It is but nine or ten years since that the idea of uniting London and Paris by railway communication was started, yet, with the capital and enterprise of the United Kingdom, the connection is already made in two directions on the English side of the Channel, and in one course through France; and would long since have extended by other lines over that country had the jealousy, distrust, and procrastination of the French government permitted.

5. Within the same period has the face of Great Britain been tattooed, as it were, with railway lines, to the extent of 2,000 miles, at a reckless and excessive cost, it is true, but still to the great advantage of the country. Belgium has spread a network of iron tracks over her fertile plains, and the formation of railways is discussed in every part of Europe with a sincerity and perseverance that presage their speedy realisation in many directions; and in spite of the pecuniary losses, which, it is hoped, will but serve in future as beacons, the positive and lucrative returns from no few of the existing lines have sufficiently broken through the circles of doubt, misapprehension, and mistrust which environ all great innovations, and capitalists now seek only for localities most favourable for the development of the resources of a country whereon to direct their speculations.

6. It may therefore be assumed that a railway through Hindostan will be characterised as an enterprise of that aspiring character, and worthy of the present age, if reasonable probabilities of ultimate successful results can be demonstrated; and, admitting that such will be proven, surely the present perfect realisation of the railway system itself, the accumulating wealth of the British empire, the settlement of the most vexatious political questions, giving assurance of the repose of Europe, indeed, of the world, all favourably unite in conducing to a satisfactory view of such a project; and, unstartled by its novelty and boldness, undismayed by its gigantic nature, the spirit of our enterprising and intelligent merchant princes will look to it not as a question of execution or non-execution, but simply to determine who are the proper and influential parties to bring such a mighty measure before the public—a measure which will be shown to present most extraordinary claims to attention, and while changing the features of the

country, practically, at least, is calculated to produce results almost startling to contemplate.

7. The nearest parallel cases to such a project as herein suggested are to be found in the numerous lines of railway already executed, and the still greater number proposed, and partly commenced, through different localities in the United States of America. The capital of our country has been thoughtlessly lent to these trans-atlantic rivals, and has made them improved communications for bringing down to their seaports those staple commodities which India can produce in still greater abundance and in greater perfection, if the proper means are applied; and as experience has since pointed out the true causes of former failures, it may be assumed the certainty of future success in this respect is ensured. The needy planters of America, having had canals and railroads made through their swamps and pine-barrens, laugh at the credulous English capitalist, and repudiate the securities given for the money which has created what they wanted; and he is not only refused either principal or interest, but sees the means assured to his dishonest rivals of bringing their productions with economy and regularity to the seaport, to be purchased by the English consumer; thus prejudicing our Indian possessions, with soils lying fallow and capabilities dormant, which, cultivated and aroused, would supersede the American, and open new and untaxed markets to those British manufactures, of which the jealousy of America is impeding the consumption, in her own states, by prohibitory duties, in foolish imitation of European countries.

8. It is, therefore, not unreasonable to suppose that the revival of our finances, and the pacific settlement of all our political relations, will be soon accumulating capital, which cannot long remain unemployed, and that the possessors will be seeking new channels for investment; nor can it be considered visionary to assume if long lines of railway in the states of Virginia, Carolina, Alabama, Lousiana, &c., to convey cotton and tobacco to the seaports can be cheaply and profitably made, that it will be equally politic, important, and beneficial to bring, by the same means, the cotton, rice, tobacco, sugar, indigo, oil, and all the many other rich products of India, to rival the production of America in our home markets.

9. If Cuba requires, and has made, railways from the interior of that island to the coast to supersede the mule and the bullock, is it not equally desirable that the example should be followed in India?

10. If it be worthy the attention of the Russian monarch to

promote railways, as he is doing, from Cracow to Warsaw, and thence to the Baltic shipping ports; and from Moscow to Petersburg, down to the mouth of the Neva, through territories sparsely inhabited, but still yielding natural articles of commerce, it cannot be matter of surprise, if those who have maturely considered the resources of British India, should deem it equally facile, equally desirable, and probably more advantageous, thus to pervade the fertile regions of Hindostan.

11. On entering into the inquiry relative to railways in Hindostan, it may be convenient to consider the subject under distinct heads, namely :—

1. Are railways through India practicable?
2. Can they be first constructed, and afterwards worked at a moderate expense?
3. In what direction should they be taken to ensure, in the most extended sense, the greatest beneficial results?

12. The first of these inquiries may be answered without difficulty. Through the thickest of the American and Cuban woods, across some of their wildest torrents, and in districts where apparently insurmountable physical obstacles existed, railways have been carried. Through every part of India native engineering talent, unaided by any European skill or science, has often overcome vast difficulties with economy and success: their architectural taste, resources, and military constructions prove their capability of executing still more difficult operations, when the experience, energy, and art of this country comes to direct them. The facility with which some most extraordinary hydraulic constructions have been completed in India by the natives, render the corresponding works for railways comparatively simple.

13. Many of the bridges, embankments, tanks, pagodas, mausoleums, and other useful and ornamental works of India, are of a far greater and more expensive character than the railways under consideration. Timber and stone are in abundance in one or other of the districts; and where the native skill, labour, or natural resources cannot furnish iron—which is, however, to be anticipated it may do in some parts with advantage—the supply from the mother country will be very little more costly to India than to America.

14. As regards the features of the country, it is evident without going into detail, and without reference to particular localities, it will be but occasionally, and at long intervals, that peculiar

points of difficulty may be anticipated—India, geologically and physically considered, consists of vast plains and table-lands, divided by ranges of mountains, with many passes and defiles, or ghauts—so termed in the language of the country—which, occasionally steep, are seldom so long or so difficult, and probably will be found much less so, when examined by the eye of an experienced engineer. With very few exceptions, the numerous rivers and water-courses intersecting the plains are only formidable in the rainy season, and during the rest of the year afford opportunity, and sure means for bridging, with facility and at moderate expense. The modern resources of engineering have taught us that the difficulties of railway gradients may be overcome in various ways, which it is not necessary at present to discuss; and daily practice in working railways in Europe and America proves, that even on lines of very great traffic, a maximum load for the moving power employed is so seldom attached to any one train, that a railway in its longitudinal section may be undulated to a much greater extent, and with far less inconvenience, from a truly horizontal, or level line, than was supposed in the outset of the creation of these means of transit.

15. In short, the practical experience and actual working of railways, both in England and America, over as steep rates of ascent, as are likely to be met with in India, show sufficiently to the engineer that the features of that country present no invincible obstacles; while the resources of labour and materials offer facilities superior to either of the other countries. Without therefore entering into the consideration of the actual means, it may be safely and conclusively stated, that whether to pass the great rivers, or to surmount the steep ghauts of India, modern engineering offers many cheap and easy appliances.

16. This naturally leads to the second question, as to the cost of construction; and here it will be at once fully conceded, that if this cost should be likely to amount to what has been the average of railway expenditure in the United Kingdom there must be a final stop to the matter. But an assumption of the probable cost of such works in India being equal to the positive cost in Great Britain or even in other parts of Europe would be most deceptive. Highly improved countries such as those, are full of artificial works and are already abounding in various improvements and existing communications which have preoccupied the ground; these, when disturbed by new constructions, must be restored; and this it is which has added vastly to railway expenditure; with such great value attached to the property necessary to be obtained, many

unforeseen expenses have to be incurred in Europe when a fresh opening of any kind, whether road, canal, or railway, has to be made.

17. The parallel of expense for India has therefore to be sought in other and less improved countries than ours. The railway system has been long enough at work to afford sufficient insight into this inquiry in a general way. The average of the many railways in England shows a gross expenditure of upwards of £30,000 sterling per English mile, while that of the Belgian railways is scarcely half that sum, namely, about £16,000 or £17,000 per mile. The average of the railways throughout Germany is £10,000 per mile, and the railways of Russia and Poland will be no more than £7,000 to £8,000, which latter sum is about the average of those in the United States of America.

18. In that country the longest and most recently finished line is the one from Boston to Albany, through the States of Massachusetts, Connecticut, and New York, a distance of nearly 200 miles across a peculiarly difficult country (more so, on the average, than most parts of India), and where labour and iron are particularly dear. This line, which is called the "Western Railway," 197½ miles long, has been completed in every respect for the sum of £1,729,645 sterling, including stations, carrying, establishment, &c., being £8,758 per mile. As more than two-fifths of this sum was for earthwork only, in which the Hindoos have much experience, it may be safely assumed that a considerable diminution from this part of the expense would be attainable, with proper management, on a Hindostanee railway.

19. Although it may be thought somewhat too much in detail, it is advisable here to give the principal heads of this expenditure in order to prove the correctness of the assumption. The above sum of £8,758 was thus divided :—

	£	
Land and fencing, about	500	per mile.
Earth and rock excavation	3,800	,,
Bridging, masonry, and works of art . . .	1,000	,,
Railway proper, or upper works (of which two-thirds for iron)	1,800	,,
Stations, &c.	300	,,
Engines, carriages, and carrying establishment .	700	,,
Sundries	158	,,
Management about 6 per cent.	500	,,
Total . .	£8,758	,,

20. Now it appears from the preceding abstract, that the great item of cost in this American railway was the leveling of the

ground, labour being high and the country rough with many streams. With the experience of all that has been previously done, and with all the resources of the country, it is clear, in the absence of the detailed and specific information, which can only be collected when this matter is much more advanced, that the sum of £8,000 per mile may be taken as the cost of first construction of railways throughout India, without reference at present to particular localities. It may be presumed that the items of land and fencing in Indian lines would be comparatively nothing; the cost of a bridged and metalled road in any of the presidencies has seldom exceeded £300 per mile hitherto. Therefore, supposing all the other sums to be as on the American railways, there would be a very large margin per mile to meet the extra expenses of formation and bridging which a railway might require.

21. In respect of cost of working there are perhaps better materials to guide the inquiry. The average of the cost of several years' working in the Belgian railways is about 4*s.* per mile per train. On the German railways it is about 3*s.* 6*d.* On the Dublin and Kingstown railway it has hitherto seldom exceeded 3*s.* 4*d.* On the North Union railway it was only 3*s.* for the last year, exclusive of the government duty and parochial taxes, of which there would be probably none in India; and the average of the working for the last two or three years on a number of railways in the United States gives us 3*s.* per train per mile; some being as low as 2*s.* 9*d.* where wood is the chief fuel. Here again, without the necessity of going into details, it is to be fairly assumed that, with the low price of Indian labour, 3*s.* per train per mile may be taken as sufficient to cover (as it does on the lines quoted) all the various expenses, which it may not be uninteresting here to abstract, namely:—

	s.	*d.*
Locomotive power	1	3
Carriages	0	3
Maintaining of railway	0	6
Police	0	2
Conducting traffic	0	5
Miscellaneous expenses	0	2
Management	0	3
Total railway expenses per train per mile	3	0

22. Now on the lines of very lowest traffic in the United Kingdom the gross receipts are 40*s.* per mile per day. And supposing the revenue on Hindostanee railways not to exceed this

sum, and that to gain it, it were needful on the average to travel over each mile six times daily, there would be a net profit per mile of 21*s.* per day or £400 a-year, which would yield five per cent. on a first expenditure of £8,000, and four per cent. on that of £10,000 per mile.

23. The cost of palanquin dak traveling in India is about 2*s.* per mile for a single person carried, and the rate for transport by camels, bullocks, or carts, is from 6*d.* to 1*s.* per ton per mile, even where a full load can be borne. Taking the railway charge at an average of $1\frac{1}{4}d.$ per passenger per mile, and 2*d.* per ton per mile for goods, which are extremely low rates, it will be seen that a very moderate traffic indeed would soon produce the above gross revenue of 40*s.* per mile per day. Indeed, on the part of the railways nearest to the seaports and to large towns, it would be so very much greater that a considerable surplus must be available to make up the deficiency on the remote and unprofitable parts of the system; and it is the very principle of a great system of railways to lead to such a result.

24. Another mode of calculating railway expenses, as deduced from the same and similar data, shows that the cost of working, including all deductions from the gross receipt, may be taken thus, namely :—

	Per Mile.
Passengers	$\frac{1}{2}d.$ each.
Coal and mineral traffic	$\frac{1}{2}d.$ per ton.
Merchandize	1*d.* ,,

and it will then remain to be considered what should be the smallest augmentation above these cost prices to make, as the railway charges, so as by low rates to induce the greatest traffic, and consequently the best returns.

25. It is presumed that a sufficient *primâ facie* case has now been made out to allow the second question to be assumed as disposed of for the present.

26. Hitherto the subject has been dealt with purely and abstractedly as a commercial speculation; but in proceeding to enter on the third and most important question of the directions in which the railways should be carried, objects of a higher class enter into the consideration and require to be maturely discussed. Still it may not be inadvisable at first to assume a specific course which shall define termini and form an integral line; such a one it is to which attention has been called, and which has, indeed, given rise to this inquiry, and into the particular merits of which an investigation must therefore be made.

27. From the great scale on which the districts of Hindostan have been formed by Nature, the distances become vast in comparison with those in Europe, and it is only on the American railways that any analogy of extension can be found ; thus the railway that has been suggested from Bombay, on the western side of the Indian peninsula, to Masulipatam, in the Bay of Bengal, would extend little short of 700 miles. In the absence of minute surveys, and especially of levels, it is not possible to define with certainty the exact course of this or of any other line in Hindoostan. Still, from the maps, books, and documents to which access has been so freely granted through the liberality of the East India Company, and the urbanity of their officers, an approximate idea may be formed of the course of the line which has been suggested.

28. On many accounts, for which on a future occasion valid reasons may be assigned, it seems advisable to proceed from Bombay, through the island of Salsette, and to form a connection with the continent at some convenient point below Tanna, by means of a floating bridge, such as in use at Plymouth, Portsmouth, &c., but capable of taking a railway train ; thence to proceed across the Concan, and by the most practicable of the Ghauts to the table-land above.

29. The difficulties here may be surmounted easily and economically by means of the atmospheric principle of producing locomotion, as now in course of construction for the extension of the Dublin and Kingstown railway to Dalkey Common on the Killiney Hills ; on this principle it has also been proposed by more than one railway Engineer to surmount difficult points such as the defiles of the Apennines between Genoa and Turin, the rugged country between the Rhine and the Danube, the Splugen pass across the Alps towards Lake Como, the passage of the Tyrol between the valleys of the Inn and of the Adige, and in other places in Europe.

30. From the table-land above the Ghauts a practicable line for a railway may be formed to the vicinity of the station and city of Poona ; thence the country is quite open, and the general and gradual descent by the great water-courses may be followed, passing near Soolapoor and thence to some point between Kilburga and Ferozabad, when it will be necessary to quit the valley of the Bheema river, and follows up the course of one of its tributaries called the Kurgan, by the town of Moolkeir, to the head of the valley at Purgee, which would be a culminating point or summit on a ridge which it seems impossible to avoid, though no serious obstacle is likely to occur. From the Purgee summit the direction will be along the course of one of the head branches of the Moosy

river to the city of Hyderabad, the capital of the dominions of the Nizam.

31. Although this part of the country is little known to Europeans by published description, the detailed part of the great trigonometrical survey of India has been completed throughout from hence to the Bay of Bengal; and guided by these valuable and important maps, though of course not yet corroborated by levels, it is considered that a practicable route will be easily obtained by the valley of the Moosy for fifty or sixty miles, when this valley will probably be found to expand sufficiently to allow the course of the railway to be turned in a south-east direction, and, perhaps, nearly straight to the left bank of the Krishna river at the great bend where the Pallais river falls into the larger stream, near a town called Moogatabad; thence, in the same direction, across the Moonyair river at the lower forks, and on by the diamond mines of Purtgall to the pass of Condapilly, and along the banks of the Krishna to the town of Bezawada—whence the passage towards Madras is generally made—and then in a direct line across the flats to Masulipatam.

32. The following would be the probable itinerary, namely:—

	Miles.
Bombay, through the Island of Salsette	32
From thence to the vicinity of Poona	90
From Poona to the south of Soolapoor	157
From near Soolapoor to about Ferozabad	85
Ferozabad to the Purgee summit	65
Purgee summit to Hyderabad	42
Hyderabad to Moogatabad	121
Moogatabad to Bezawada	43
Bezawada to Masulipatam	44
Total miles . .	679

And it must be observed that as the detailed character of the line cannot be known, and may require deviations and detours to be made for the purpose of avoiding difficulties and facilitating gradients, it is expedient to call this about 700 miles, or, say, an expenditure of six millions sterling, which, from the generally easy nature of the principal part of the distance, and the facilities of obtaining labour and all materials except the rails, may be taken as a safe approximate estimate.

33. It has to be inquired what pecuniary return, and what general and political advantages may be anticipated from a line of railway in the above direction, not omitting to consider the probable future development of resources, and opening of additional

facilities of communication to points beyond the terminus, as well as the general bearing on the means and resources of the other parts of India not directly pervaded or served by the contemplated line.

34. In a commercial point of view there is no question that the greatest advantages would be obtained for the trade of Bombay by opening up such a communication with the interior as the proposed railway. At present the western part of India may be said to be almost without roads at all, and none that can sustain any heavy commercial or military traffic. Into Bombay itself there are at this time only two lines leading; indeed, for the nearest twenty-five miles, but one road. Throughout four of the collectorates adjacent to Bombay, namely, Poona, Ahmednuggur, and the two Concans, an area of considerably upwards of 30,000 square miles, and fully equal in superficies to the whole of Ireland, there were, within the last three years, little more than 400 miles of roads, of which only one-half were passable at all; and at present there are scarcely 600 miles, whereof eighty or ninety only are practicable for carriages in the rainy seasons, which last for fully one-third of the whole year.

35. All the towns and posts of the interior are, therefore, so many isolated points during the rains; and however important it might be either in a military or commercial sense, it is impossible to pass heavy carriages along the roads, which have been constructed without any care or cost as to their foundations, and have no bridges at all, with very rare exceptions, and but few ferry boats.

36. Over many of the roads, especially through the Ghauts, wheeled carriages cannot pass at all, and yet the slight improvements which have taken place of late years demonstrate the truth of the remark—prevailing in India as in all other parts of the world—of the vast increase of intercourse where facilities of communication are afforded. Thus, by a slight improvement in the road leading to Nassuck, the number of carts coming with grain into the town had quadrupled in two years. On another road through the Concan, and within forty miles of Bombay, where formerly there were no carts used for traffic at all, there are now great numbers, and every wheelwright in the different villages has full occupation in constructing new ones. On the only good road, namely, between Panwell and Poona, the number of carts passing the Bhore Ghaut had quadrupled within four years—the number being now nearly 700 daily.

37. On the other hand, there is a very great cart traffic through

another district of the upper country, but the carriage road stops at the top of the Tholl Ghaut, about 70 miles from Bombay. Here nineteen-twentieths of the goods are shifted on to bullocks and thus conveyed for the rest of the journey, the carts returning empty over 200 or 300 miles of country, although, were there a good road to the shipping place these same carts might take into the interior a return lading of salt, hardware, &c. &c. which has now to be transported by bullocks, thus limiting and diminishing the consumption by this needless expense of carriage.

38. These instances might be greatly multiplied if necessary. The consequences may be readily inferred. Traffic and commerce are not only greatly impeded, cramped and broken up by false expenses, but the existing trade is turned in another direction. For instance, the chief products of the Oomrawattee districts, all westward of Baulapoor, already find their way to Bengal by way of Mirzapoor and the Ganges: although, by going to Calcutta instead of Bombay, the merchants have from 100 to 200 additional miles of land carriage, besides all the water transport, down the river of many hundred miles.

39. It would, therefore, seem incontrovertible to insist that a main trunk line of railway pervading the wide fertile districts eastward of Bombay would present all the advantages of a navigable river open at every season of the year; and, if made, would be joined by various branch roads suited to the traffic from the several towns and districts to a great extent on either side; the best description of firmly-made and well-bridged road, costing from £200 to £300 per mile, and the minor routes for fair-weather traffic averaging only about £50 per mile.

40. In carrying a line of railway across the peninsula of India the leading feature, as in that of any other great railway system, must be to connect the extreme points on each coast, and to leave the districts pervaded by the main trunk to provide communications, by public or private means, to the nearest or most eligible points. The institution of a principal and leading line will derive its prosperity and success by the number of ramifications from its trunk, at the same time imparting great facilities to the country: the benefit being mutual—the support interchanged.

41. The same arguments apply to the mercantile connection between the interior of the eastern side of the peninsula and the port of Masulipatam; and there will be, of course, a point in the dominion of the Nizam, probably somewhat east of Hyderabad, where the current of traffic will divide, flowing westward to Bombay and eastward to the Bay of Bengal. The whole of the

immense territory between Soolapoor and Masulipatam may be said to be totally destitute of any but the very rudest means of transport; and the transit of a railway will present to the districts on each side a double line of coast, as it were, on which each station would be a port, and would become a depôt for the collection of the products of the country and for the distribution of the manufactures of Great Britain, at prices so greatly reduced by the saving of the present cost of carriage as to place them within reach of a class of persons now wholly unable to obtain them, and at the same time for these same individuals present a local mart established for the fruits of their own industry.

42. Judging from the latest reports of the Bombay Chamber of Commerce and by the returns from the various collectorates, there appears no reason to doubt, even under all the existing difficulties of bad culture, tardy improvement, unskilful preparation of the produce for market, and the limited means of lateral conveyance, there would be a traffic sufficient to form a fair revenue for a railway.

43. For instance, the "Barsee cotton" of the Bombay market is collected at the town of that name from two or three small districts only of the Nizam's dominions; and the annual quantity sent from them was, four years since (the latest accounts), upwards of 40,000 bales, all which must have been carried full 300 miles on bullocks or in bullock carts from the places of growth.

44. The statements of Dr. Gibson, Professor Royle, and other competent authorities up to the most recent periods show that there is no limit to the production of cotton, sugar, silk, tobacco, and numerous valuable staple articles of produce and commerce as far as soil and climate are concerned. A more careful attention and greater skill bestowed, will always command the Bombay market for this produce; and the introduction of European capital, enterprise, energy, and system will gradually, and no doubt rapidly, produce this effect if proper arrangements and suitable opportunity be afforded.

45. In regard to passenger traffic, this must be the natural consequence of economy and expedition in the means of conveyance. In Belgium, Ireland, Scotland, Germany, &c., where low rates exist, the movement among the very lowest class has been most extraordinary, and the increase seldom less than fourfold.

46. But to complete the statistical information and detailed returns necessary to be obtained and investigated, to solve accurately the question of traffic, would require much greater time than it has been possible to devote to the subject, even if the mate-

rials existed at all, or at any rate if existing in this country. The same, indeed, with respect to the estimates of construction; but there remains the very highest probability that the more these inquiries are gone into in detail, the more likely are they to result in proving that the requisite capital would be comparatively small, and the probable returns from merchandise and produce only, very great.

47. To take, however, a more extended view of the subject, the railway communication from Bombay to Masulipatam should be considered as part of the probable future route to China, whereby, in connection with the contemplated passage across the Isthmus of Siam from Mergui, on the Tenasserim coast, to the Gulf of Siam, the distance between the Straits of Bab-el Mendib and the China Sea would be reduced to 1,000 miles less than by the present route, *viâ* Bombay and Ceylon; and, what is a greater advantage, there would be a diminution of 1,800 miles of the sea voyage. Even in comparison with the route direct from the Red Sea to Ceylon, the advantages would be extremely great; for though the positive gain in distance would not be more than about 200 miles, there would be 1,000 miles less of sea.

48. This will be shown at once by the following abstract of the distances on the respective routes:—

Present Sea Route by Bombay, Ceylon, and Singapore.		Direct Sea Route to Ceylon and Singapore.		Overland Land Routes across the Peninsula of Hindostan and Siam.	
	Miles.		Miles.		Miles.
Socatra to Bombay	1,400	Socatra to Ceylon .	1,900	Socatra to Bombay	1,400
Bombay to Ceylon	1,300	Ceylon to Singapore	1,700	Overland to Masulipatam .	700
Ceylon to Singapore	1,700	Singapore to Macao	1,600	Masulipatam to Mergui . .	1,200
Singapore to Macao	1,600	All sea.—Miles .	5,200	Across Siamese country . .	100
All sea.—Miles	6,000			Siam to Macao .	1,600
					5,000
Total additional distance . .	1,000	Total additional distance . .	200	Deduct land journey . .	800
Total additional sea voyage .	1,800	Total additional sea voyage . .	1,000	Sea voyage.—Miles	4,200

49. As regards the general advantage to Madras and Calcutta, the line across from Bombay to Masulipatam will place both these ports in a better situation to communicate with the mother country; for, either by land or water, Madras may be reached in two days

from Masulipatam, which latter by railway would be only from 24 to 30 hours' journey from Bombay, being a gain of five days over the present mail time, and still more over the Bangy post. The gain in time to Calcutta by land mail would also be about five or six days, computing a week's journey from Masulipatam. It is probable, however, that regular steamboats would ply from the latter port both to Madras and to Calcutta.

50. In a military point of view, also, the contemplated railway must be highly advantageous; and affording such increased facilities and diminished time and expense of communication to Madras, Calcutta, China, and all the Eastern Archipelago, it is no more than right to assume a great traffic, doubtless yet to be created, but which cannot fail to arise.

51. To give due effect to the acceleration of the traveler, the merchant, the soldier, and the statesman, arrangements should be simultaneously made to put on regular lines of steam-packets; nor should the probability of forming another railway across the Isthmus of Suez sooner or later be lost sight of; and it may be interesting to state that serious negotiations are now going on with several of the European Governments, the effect of which, if brought to a satisfactory conclusion—of which there is little doubt—will be to obtain a railway communication from the English Channel to the Mediterranean at some eligible port in Italy, independent of France, ensuring some further reduction of time and a certain uninterrupted transit. All these public advantages are sufficiently evident without it being necessary to enlarge upon them, and bearing as they do on the question of the Hindostanee railway, become powerful arguments for its support.

52. It must, however, be distinctly stated that most of the general arguments in favour of railways in India, not even excluding the combination which improved communication between Europe and China, as will be shown, are almost as equally applicable to any line extending from Bombay eastward, as to the supposed railway from Bombay to Masulipatam, which, in strictness, ought to be investigated purely on its local merits; when, after deciding favourably on the great principle of having railways at all, the next point to be mooted is the precise direction. Considered in this light, several doubts may be reasonably started against the above line: such as the eligibility of Masulipatam as a steam-packet station during all periods of the two monsoons, and the fact of so large an extent of territory to be pervaded—fully one-half of the entire distance between the two coasts—not appertaining directly to the British territories. The former might be left to

the decision of competent naval authorities, but it is difficult in regard to the latter.

53. The ultimate success of so vast an undertaking as an Indian railway system must necessarily be based on the future improvement of the country and the fuller development of its resources; to effect these indispensable results will require every encouragement, facility, advantage, and support from the ruling powers, and every freedom from the contingency of transit-duties and local and uncertain impediments: or, granting all apprehensions on this subject to be removed, still, the unwise rule of the native governments—so long exercising a prejudicial, and too often baneful and fatal, influence on their subjects—grinding them down by excessive taxation and restrictive measures—gives but too much reason to apprehend that profitable returns might not be so soon reaped from districts such as those not exclusively under British control; and Confidence, that spoiled child of Peace and Freedom, reared by Experience, might long hold back her aid in enabling the beneficial results of such a mighty speculation to be speedily realised.

54. Further, it has been supposed that some serious objections on the score of climate might be brought forward respecting the location of the railway through the northern Circar between the Krishna and the Godavery rivers. It is also clear, from the geological features of the whole of this particular line, that there is not any coal; and latterly it has been demonstrated that there is no hope of any of the minerals which former accounts had held out as abundantly existing in the eastern districts of the Indian peninsula —the magnetic iron ore perhaps excepted—nothing in addition to the rich vegetable productions of the country, save, possibly, what might be hoped from a better mode of working those almost abandoned diamond mines which, under the name of 'Golconda,' have been so famous for ages, and whereof the same authorities who so dispassionately broke down all expectation of copper, lead, and similar metallic veins, seem to consider might yet, under European management, prove sources of wealth to enterprising adventurers.

55. Not that it is doubted that from the natural productions of the soil only, advantageous returns may be derived; but if localities are to be found combining mineral as well as vegetable wealth, such localities are naturally preferable; considering, also, that for any great military purpose of defence or intercommunication in the various parts of Hindostan, a line from Bombay to Masulipatam may not be found the best, it becomes desirable to seek for, or at least to discuss the eligibility of, other routes which may not only serve the purposes of commerce and internal com-

munication to a still greater extent, but, by combining many other important public and natural advantages and desiderata, enlist not only the sympathies of all classes of the community, through the greatest area of wealth, population, and industry, but the cordial support and co-operation of the Government of India and that of the United Kingdom.

56. In short, to follow out to its uttermost the grand principle enunciated and adopted by the East India Company and by Parliament when the great question of steam navigation to Asia was discussed in 1834, namely, "If this measure were undertaken "it ought to be executed on a large and efficient scale, and that "between doing it thus effectively and comprehensively and not "doing it at all there is no advisable medium." In such a principle all the merchants of the East most cordially concurred, and there cannot exist a doubt that a similar and simultaneous accord and combined effort can alone bring to maturity this corresponding enterprise which it has been attempted here to investigate and recommend. In fact, to do less would be inexpedient even on the score of economy; for, viewing the expense as a great whole, the cost of establishing and maintaining such a work as a railway would be but inconsiderably increased by giving it a further practicable extension beyond the minor measure first suggested, and the benefits, from being comparatively partial, would be extended in a vastly augmented proportion to the original expenditure; for in carrying out a magnificent project such as this, in which the account total is by millions, it becomes a wise and politic step to render it as comprehensive as possible.

57. With these principles therefore as a guide to enter into the discussion of some other direction for the exercise of a bold but deliberate and matured spirit of speculation, or rather demonstration of national foresight, let it be at once supposed that a line be sought and traced for a railway from Bombay to Calcutta and its particular merits investigated. Measured along the arc of a great circle the absolute distance between Bombay and Calcutta is little more than 1,000 miles, the great military post of Nagpoor being nearly on the line.

58. There are, however, physical difficulties herein of no ordinary kind, and those acquainted with the topographical features of the country know, that for at least one-third of the distance such a course would be over wild hills, amid a savage population, and through a desolate and almost uncultivated country; but partly subjugated by the Mahommedan invaders of India, and even at the present time but little known. There is also the former

difficulty of half of the route only being within British dominion, and other causes of objection similar to those which might be urged against the line to Masulipatam.

59. It is well known to geographers that at the southern base of the Great Vindhyan range of mountains, running from west to east, there flows the Nerbudda river, the head waters whereof rise within a mile or two of the sources of a principal branch of the Sone river, which is one of the great tributaries of the Ganges, and thus what may be called a natural engineering line exists between the Gulf of Cambay and the Bay of Bengal; and if a course be taken from Bombay towards Calcutta so as to fall into the valley of the Nerbudda river, and if that stream and the Sone be followed as far as necessary on to the great plains of Bengal, an easy and not very indirect course to Calcutta would be obtained, having the advantage of passing through or near most of the great coal and iron districts which have lately been discovered; pervading at the same time an extremely fertile district, nearly the entire of which is British territory; a very large portion highly cultivated and thickly peopled, and but few parts of a wild, and none of a sterile, character; and everywhere capable of the very highest degree of improvement, and of furnishing all the necessaries of life, and the most valuable productions, for which Europe offers an unfailing market; and in addition to all the local advantages and commercial benefits to the country itself, and to the great empires at each extremity, such a line forms remarkable means for facilitating several great national objects.

60. In attempting to describe the route such a railway would probably take, it is done with similar reservations and remarks to those applied to the line first considered. Starting from Bombay, the island of Salsette would be traversed to Tanna, and the main land be attained in the way before mentioned by a steam floating bridge; passing thence, probably, to the north of Callianee, the line would be directed by the most eligible ghaut in the Syadree range to rise into the upper country above some of the head waters of the Godavery river, then proceed in the vicinity of Nassuck and Guntoor, filing by one of the ghauts of the Injyadree range into Candeish.

61. The course would take this fertile province in its longest length, and be directed upon the large and important city of Bhoorampoor, in the rich and flourishing valley of the Taptee river, and near the celebrated fort of Adjyeghur on the south side of the Sautpoora range. To this point the British territories extend without interruption. A passage through the ridge may

be found with little difficulty, and thus take the railway into the valley of the Nerbudda river, attaining the banks of that great stream somewhat to the east of Hindia, when the line would again enter our dominions, having passed for about 90 or 100 miles through the south-east corner of Malwa, over a district belonging to the independent state of Sindia.

62. From thence the course will be along the valley of the Nerbudda, by Hoshungabad—where coal and iron are found—to the meeting of the waters at Sacur, still in the coal-field, and near the wealthy town of Jubbulpoor, the capital of these districts, situated on the main stream of the Nerbudda, about 30 miles east of Sacur; from this latter place the northern branch of the river would be followed to the culminating point or summit, and then over the ghaut to Belhari, a town situated at the very head of a great branch of the Sone river; this branch would be pursued down to its junction with the main arm of that stream, and the line go still down the valley, probably on the northern side, until past Burdee, to the mouth of the Coyle river, passing by the great coal-fields, and probably about 50 miles from Allahabad, Mirzapoor, Benares, and Ghazipoor. From a little east of Belhari for a distance of 40 miles the line would intersect the south-east angle of Bundelcund—which here extends across the north branch of the Sone river—afterwards keep for about 100 miles in the territories of Rewah Rajah, re-entering the British possessions near Burdee, not again to leave them.

63. Emerging on to the great plains of the Ganges the course would then be brought not more than 50 miles from Patna, and near Gaya and Berar, both large and populous towns, the former known as a place of extraordinary great annual religious resort; then, following a lateral valley eastward and over a small ridge of hills, the line would descend to the streams which form the sources of the Hadji and Damoora rivers, pursue the general direction of their valleys by the coal-fields lying between them and to the vicinity of Burdwan, and from that town proceed direct to the right bank of the Hooghly river, opposite Calcutta.

64. It should be observed that there is no river along the whole of this long range of country likely to present any serious difficulty whatever, or to require any peculiar construction, and it may be repeated that the successive passage of the first three principal ranges of mountains and of the other two summits may be satisfactorily effected by means of the atmospheric system before alluded to.

65. Should, however, circumstances, which will be presently

discussed, make it desirable or necessary to push the line of railway well towards the north-west frontier of India before turning eastward towards Bengal, then what may be styled an alternative course may be found in the following direction, namely:—

66. Leaving Bombay and attaining the main land from the island of Salsette, as previously described, keep the railway nearly due north and parallel to the coast, cross the Taptee river near Surat and gain the banks of the Nerbudda in the vicinity of Baroche—sometimes called Broach—then follow that river upwards to Hindia and Hoshungabad, joining on to the route previously described.

67. Such a course would, however, add fully one hundred miles to the distance, probably encounter serious and as yet unknown difficulties along that part of the Nerbudda where it forces a passage through the approaching mountains, and traverse for 250 miles wild territory in Ghuzarat and Malwa, not belonging to Great Britain, chiefly under the dominion of Holcar, but including parts subject to Kotah and to Sindia. Such a detour under such circumstances would however certainly be admissible from a high grade of political and commercial considerations, the value whereof must be judged of by those well versed in this subject, and capable of taking the most enlarged views.

67. The following would be the itinerary of the lines from Bombay to Calcutta by Nassuck, Bhooranpoor, &c., as first described:—

	Miles.
Bombay through the island of Salsette	25
From thence to the vicinity of Nassuck	75
Nassuck to the Injyadree range, near Chandore	40
Through Candeish to Buooranpoor	150
To the Gynial river, in the Nerbudda valley, east of Hindia (coal-fields)	100
To the Towah river, near Hoshungabad	40
To the forks of the Nerbudda river at Sacur	100
To the summit, west of Belhari	80
To the fork of the Sone river	55
To the mouth of the Goput river, near Burdee	90
To the mouth of the Coyle river (Palamow coal-field)	100
To the summit east of Gaya	100
To Oberah, between the Danwora and Hadji rivers, in the centre ot Burdwan coal-field	110
To Burdwan	46
To the right bank of the Hooghly river, opposite to Calcutta	54
Total	1,165

68. And for the causes before assigned for augmenting this distance, on account of probable circuits that may be found necessary in order to evade particular difficulties, or to obtain easier rates of ascent through the Ghauts, this should be called 1,250 miles, which, at the average rate of £8,000 per mile for a single line of railway with passing places, but prepared for a double road, will require the sum of ten millions sterling, which may be considered a minimum sum, as sufficiently explained in the first pages of this statement.

69. If the more circuitous line by Surat and Broach, and along the entire course of the Nerbudda river, be adopted, the itinerary would be as follows, namely :—

	Miles.
Bombay, through the island of Salsette	25
Thence to near Damoora	75
To the Taptee river, near Surat	60
To the left bank of the Nerbudda, east of Broach . .	40
Along the Nerbudda valley to the Gunial river, east of Hindia	280
	480
Thence to Calcutta by the former route	805
Total . .	1,285

which, with the addition for probable detours, will make an increase of about 100 miles over the other line.

70. For the purposes of a railway across the Indian continent, between Bombay and Calcutta, such a circuit becomes only the question of a few hours; and, postponing a comparison between the two routes, it may first be inquired whether the communication to China may be advantageously extended from Calcutta.

71. Looking forward to the vast and increasing importance of establishing the most certain and expeditious connection with the Chinese territories, over which a dominating influence, at least commercially, must henceforth be established by Great Britain, the passage across the Isthmus of Malay from the Mergui archipelago to the Gulf of Siam, before alluded to, will probably form a portion of the future line of communication. In this case, if the railway from Bombay to Calcutta become included therein, it will be seen by the following abstract of distances, as compared with those given in a preceding page, that the advantage in time at least would just preponderate over the route proposed by way of Masulipatam :—

Sea and Overland Route, from the Red Sea to China, by Bombay, Calcutta, and the Siamese country.

	Miles.
Socatra to Bombay	1,400
Bombay to Calcutta	1,300
Calcutta to Mergui	1,000
Across the Siamese country	100
Gulf of Siam to Macao	1,600
Miles .	5,400
Deduct land journey . .	1,400
Sea voyage . .	4,000

72. Thus it will be perceived that by such a line the length of the sea voyage would be reduced 1,200 miles out of the entire course from the Red Sea to China direct, by the south of Ceylon and Singapore; and, although 200 miles are added to the geographical distance, yet computing by hours, which steam has taught us to do, and taking the rate of railway to sea—steam traveling as 3 to 1—there will be an advantage of nearly four days in time; and, considering that the monsoons would not affect the voyage between Calcutta and Mergui in either direction, two or three days more may be reckoned upon. As compared with the present arrangement which makes the long circuit round the Indian peninsula by Bombay, there would be a positive gain of upwards of a week, but as contrasted with the route of Masulipatam, the advantage however would not be more than one day.

73. Admitting the passage across the Siamese country not to be carried into effect, the abstract of distances by Calcutta would be thus:—

	Miles.
Socatra to Bombay	1,400
Bombay to Calcutta	1,300
Calcutta to Singapore	2,000
Singapore to Macao	1,600
Total . .	6,300
Deduct land journey . .	1,300
Sea voyage . .	5,000

being an increase of 1,000 miles of sea-going route. Still, computing by time and not by mere distances, the correspondence and intercourse would be equally accommodated as by the other competing lines, for, compared with direct voyage from Socatra by Ceylon, there would only be the difference of a day, or at most two, which the advantage of not encountering the monsoons between

Calcutta and the Straits of Malacca, either going or returning, would very much more than compensate for, and, as opposed to the present mode of communication, there would be an actual saving of two or three days.

74. The itinerary by Masulipatam, if the shortening by Mergui and the Gulf of Siam were not effected, would be :—

	Miles.
Socatra to Bombay	1,400
Bombay to Masulipatam	700
Masulipatam to Singapore	1,900
Singapore to Macao	1,600
Total	5,600
Deduct land journey	700
Sea voyage	4,900

75. This would give an advantage of half a day of sea and a whole day of land journey to the Masulipatam line; but it may be readily granted that the importance of having a direct means of correspondence between China and Calcutta, on the great chain of communication between eastern Asia and western Europe, may be well placed as a set-off against this, the only one of so many various directions in which a very small preponderance of time can be found, over the contemplated overland route through the Bombay and Bengal presidencies.

76. The only drawback to this arrangement of railway and correspondence is, that the trade and presidency of Madras are altogether excluded; nor is there any possibility whereby it could be embraced in any general system except by the Masulipatam line. Indeed the advantage this latter route presents to Madras is probably one of the greatest arguments in its favour. Still, looking at the larger contemplated measure in its evident range, it must be admitted even by those most interested in the prosperity and advancement of the Carnatic, that it is impracticable by this one line only to extend to that portion of the country the advantages which such a line must bring to almost all the rest of India; and it can only be hoped that the success of the proposal herein suggested may be the means of stimulating exertions that will terminate in forming a great south-eastern trunk railway from Bombay which would not be longer than that to Masulipatam first discussed.

77. If the principle of establishing railways in India be taken up as great national undertakings, either directly by our Government and the East India Company, or in connection with and in

aid of high-minded individuals, united in one or more private associations, there is no doubt a railway to Madras, as well as one to the north-west frontier of India, will thereafter be established. Although Madras and its dependencies could not, for the present, be included in the great series of intercommunication, another district would have advantages and facilities extended to it of which it is now in want, and which may produce most valuable results.

78. The new and important colony and fine harbour of Amherst, and the adjacent town of Moulmein, in the Gulf of Martaban, near Rangoon, and the mouth of the Irawaddi, and also the settlement of Mergui, would be put in direct connection with this country even if the line across the Tenasserim province to the Gulf of Siam be not made. A rendezvous station between Calcutta and Singapore, for the steamers to communicate with Amherst and Mergui, might be established at Narcondam island, which is visible at a distance of sixty miles round its horizon, and lies in the direct track.

79. The high-raised expectations, already in course of realization, of the prosperity of these two settlements, and the great commercial advantages rapidly developing therefrom, merit the boon which a line of intercourse thus brought to their shores would afford; and though it is far from being assumed that this could be accepted as any compensation for not serving Madras, yet as that cannot be done, at any rate it is at least well that such thriving colonies as Amherst and Mergui can have a benefit like this bestowed on them. Before quitting this subject it may be noticed that there exists every reason to believe that a road for elephants and wheeled carriages formerly existed between Mergui and Banguaroon, the plain on the west side of the Gulf of Siam, where the steam-packet station has been contemplated for forming a more direct communication with China by Macao, from which it is distant little more than a week's steaming.

80. Having thus, it is submitted, satisfactorily established the fact, that a railway between Bombay and Calcutta will be the best and quickest mode of communication between England and China, let the local advantages of this line be the next point of inquiry. It seems needless to repeat here the general arguments adduced in reference to the line from Bombay to Masulipatam, since they are strictly applicable to this projected substitute, which pervades in a north-east direction, provinces more rich, more fertile, more salubrious, and more under the control of Great Britain. Details are impossible in this present stage, but abun-

dant general information is extant to show what capabilities now exist, when fair means of development are presented; nor must the sources of traffic be supposed to be confined to the mere line of railway or to the closely adjacent country. If, at present, the merchant transports, at heavy cost and risk, the productions of Candeish, Aurungabad, Berar, Malwa, &c., many hundreds of miles by the rudest means, to Bombay in the west, or to the Ganges in the north, thence to descend many more hundreds of miles to Calcutta, what may not be expected when the railway, pervading the land like a mighty river, will offer at every station a market, or, at least, a point of embarkation for the collected produce?

81. A lateral transport of one or two hundred miles to attain the railway is comparatively trifling to what has to be traversed at present. Even at an increase of 50 per cent. upon the prices quoted as the proper mercantile railway charges, produce could be brought from any part of the districts thus penetrated, either to Calcutta or to Bombay, at less than 1*d.* per lb.—including the cross-country carriage—to the railway, and from most of the richest districts at half that cost. With the economy and rapidity for moving over the country afforded by the railway, and with the facilities for collection and inspection, the frauds in packing so bitterly complained of, the neglect in cleansing and preparing, the errors and prejudices, and the attention to less useful articles of culture will all be removed. The monopoly possessed in so extraordinary a degree by that remarkable class of traders and their agents, known under the general name of 'Marwarries,' will be broken through. The 'Ten Photodars,' as they are called, who have the command of the markets in every bazaar, from Bombay to Calcutta, and from Delhi to the banks of the Krishna—over nearly a million of square miles—will find watchers of their frauds in collection and distribution, and rivals in their business at every step, when a few hours will convey the English merchants or his active representatives, to any of the many stations on the railway, whence the most distant mart would be speedily attainable.

82. The direction between Bombay and Calcutta will be easily regulated in its details, as any minor deviations will not affect the great bulk of traffic; and until further progress in this investigation is made, the general course pointed out as going direct from Bombay to the valley of the Nerbudda may be assumed, if such direct route be, under all circumstances, preferable; and from the Nerbudda the line passing along the extensive coal and iron

fields, and approaching the great commercial and military ports and populous cities in the provinces of Allahabad and of Berar, will combine, in its course, most of the favourable points which generally influence the selection of a railway. There will then only remain to investigate the various circumstances which might lead to making the grand detour of the line on the western side of India which has been before mentioned.

83. In reference to this question, it should be observed, that a distinguished military officer, in the service of the East India Company, left England very recently on his return from a visit to London, made for the purpose of collecting the best materials to enable him to form an estimate of the probable cost of forming a railway from the farthest north-west port of the Bombay presidency at Deesa, near the head of the Gulf of Cutch, through the province of Ajmeer, by Balmair and Jessulmair, and across the desert of Sinde to Bukhur on the Indus, near the great commercial Affghan city of Shirkapoor.

84. Assuming that such a communication is called for and much wanted, as will indeed be shown, then it may be inquired whether a certain extension to the south from the suggested line, as far as Broach, might not be a weighty argument in favour of turning the main trunk of railway from Bombay to Calcutta to meet it. Suppose this to be done, and the lines all completed, then, casting a glance over the map of India, how forcibly we must be struck with the powerful union effected throughout Hindostan by such a series of railways, especially could the south-east line to Madras be included within this system!

85. From Bombay to the banks of the Nerbudda river, near Broach, would be 200 miles along the principal line; from this place Calcutta is distant about 1,000 miles, and the nearest point on the Ganges by railway—being in the vicinity of Allahabad or Mirzapoor—is within 700 miles. From Broach to Deesa is 180; and from Deesa to Bukhur about 320 miles, thus making the north-west branch to the point of safe and uninterrupted steam-boat navigation on the Indus 500 miles. The station at Bukhur being thus distant, in time—by means of the almost talismanic railways—three days from Calcutta; two days from Allahabad; one and a half from Bombay, and about three from Madras; Bukhur being also only about 500 miles, or two days' steam-boat journey, from Attock, Lahore, and all the other points at the heads of navigation on the five great branches of the Indus.

86. The real difficulties against duly profiting by the opening of the important river all lie below Bukhur, from the continued

changes of its course between that place and the sea, and from the dangerous ever-shifting channels and shallow waters at the mouths of its Delta. Above Bukhur the navigation is clear and open up to those towns now unhappily the seat of war, but which it is hoped will soon be over and give peace to only peaceful emporia of commerce.

87. What a host of ideas arise in the mind at the mere suggestion of the grave and probable adoption of such a combination as would place these remote points of India within as many days as they are now almost months distant from the centre of our resources, and that not simply for despatches, but for armies and all their 'matériel!' What a contrast of the capability presented of rapidly transporting supplies of troops and munitions of war, compared with the trains of camels traversing the desert, each with a cannon-shot swinging on either side, or with the sickly march of the jaded and spirit-broken Sepoy!

88. The cost of such a branch railway from Broach, by Deesa, to Bukhur and Shirkapore, with the extra expenses incurred in taking the detour by the estuary of the Nerbudda, would be covered by five millions, which, with the charge for the line between Bombay and Calcutta, is an aggregate of sixteen millions sterling, or as many crores of rupees; and well-informed persons have asserted that such a sum would barely cover the expenses of the Affghan war!

89. But peace restored, such a railway would be advantageously employed in taking merchandise for the natural wants of the countries beyond the Indus and Sutlej. These require to be supplied with the metals and manufactures of England, the silks and indigo of India, and the teas and spices of China and the Eastern islands, of all which articles large quantities are consumed. In return, from the Punjaub cotton and sugar, crystal salt, saltpetre, &c., might be exported to any extent. From Mooltan, tobacco of the finest quality in the world. Almonds, raisins, currants, and groceries (already supplying all Upper India) from Cabool. From Affghanistan, through Shirkapore, oils, drugs, dye woods, &c., and assafœtida, used greatly in all parts of the world, but throughout India as a daily condiment. At present the trade is carried on from Bombay by coasters to Bhownuggur—a small port on the north side of the Gulf of Cambay—and thence by canals to Palee as a central point, branching from thence to Shirkapore and to Amritzer, near Lahore. English piece-goods, tea, spices, cochineal, indigo, quicksilver, &c., are sent through at a cost of 7*d.* per lb. to the latter and 6*d.* per lb. to the former place, the time occupied being two months and six weeks

respectively; this is at the rate of about 1*s.* per ton per mile, including the sea voyage; the canal traffic costing 18*d.* per ton per mile.

90. From Calcutta spices, metals, &c., are sent nearly 1,000 miles up the Ganges or the Jumna, and thence carried by hackeries 400 miles to Amritzer, at a cost of from 2*d.* to 3*d.* per lb. for the entire distance from Calcutta, of which the river freight is not less than 2*d.* per ton per mile, and the hackery charge about 8*d.* per ton per mile; the period of transit between Calcutta and Amritzer occupying nearly five months.

91. With all these disadvantages of expense and delay in transit, the annual value of the Bombay exports to Amritzer, with 350 miles of sea and 800 miles of land-carriage, is officially stated at half a million sterling, of which one-fourth is in English piece-goods; and to Shirkapore, about £50,000 sterling. The value of the exports from Calcutta to Amritzer is about £150,000, with 1,000 miles of water and 400 miles of land-carriage.

92. With the facilities of a railway route to Bukhur, and steam-navigation on the rivers, certainty, regularity, and great economy of carriage must ensue, and especially would an opening be made for receiving the produce of the country in exchange for the imports —for want of all which there is a great limit to the consumption of English piece-goods, metals, &c., &c., these being now considered great luxuries, but which would hereafter become articles of general use. And it must be again remembered, that it is only by our taking in exchange the natural productions of Upper India that the inhabitants can afford to buy our manufactures. It would seem, from the latest accounts, that it is almost hopeless to navigate the Indus below Bukhur with success; the railway is therefore the only resource; and there can be no reasonable doubt that the increased trade and facilities will repay the cost, if brought within the amount stated, of which satisfactory assurances can be given. A great deal of valuable information on this head is to be found in the Report of the Chamber of Commerce of Bombay, for the fourth quarter of 1839-40, dated in September of the latter year, particularly in the notes of Colonel Ward.

93. In recapitulating the lines of railway which might be advantageously opened in India, we have in round numbers the following :—

ABSTRACT OF DISTANCE AND EXPENSES.

DISTANCE.	Miles.	Sterling Money.
Bombay to Masulipatam	700	£ 6,000,000
Bombay to Calcutta (say about)	1,300	11,000,000
North-west branch to the Indus to include extra cost of detour of Calcutta by Broach	500	5,000,000
South-east branch from Bombay to Madras, as a substitute for the Masulipatam line	700	6,000,000
Total miles . .	2,500	22,000,000

94. The execution of the entire of this system would probably be too great for private enterprise—certainly so without the direct aid, and perhaps the participation, of Government and the East India Company. Yet it is, at any rate, desirable to keep the whole in view; and to whatever extent individual and associated speculation may deem any portion of it worthy of being undertaken, a general and comprehensive system, such as above developed, should be laid down from the commencement; to be followed out, at once or by degrees, as circumstances may admit. Granting that it can be satisfactorily shown—and it is deliberately and conscientiously undertaken to be so demonstrated—that twenty-two millions sterling could effect the whole, or 'pro ratâ' for whatever distance executed; and that three shillings per train mile would cover all expenses, it becomes easy for the merest tyro in Indian statistics and its political and military movements, to determine whether there does not exist the very best grounds for believing that a reasonable interest on the expenditure may be depended on by the capitalists, without taking into account the advantages to the nation of a henceforth secure tenure of the frontier, and of all our interior possessions, or of the improvements certain to follow by colonisation through all the districts pervaded, and far beyond them; giving European example of what may be extracted from the soil, which the most prejudiced and most apathetic of the native possessors and cultivators will not fail to follow, and for want of which example it has been observed that, "the Indian cultivator must at present literally be bribed to his own advantage."

95. It is presumed that enough has been made out to justify those who are sufficiently interested in, or may be 'à priori' disposed to take up this important subject of railways in India, in going

into a more detailed investigation, which may be likely to lead to some practical result. A survey will in some shape be necessary, and various authentic returns, which may probably only be satisfactorily obtained in India. If the line to Masulipatam be preferred, the task will be shorter and more simple. If the bolder and more comprehensive measure of the Calcutta railway be chosen, or only one or more portions of it, a decision will be first required on the direct or the circuitous line between Bombay and Hoshungabad; and the greatest consideration will have to be brought to bear on the solution of this important question. Hereafter it may not be unreasonable to suppose that both lines may be constructed; but, as the first step, a choice must be made between the two, which will of course be swayed by the part taken by Her Majesty's Cabinet and the Court of Directors of the East India Company. This leads to the point where the matter ceases to be debateable on private considerations, and leads to an attempt being made to investigate it wholly on great public grounds.

96. Without observing further on the policy of the East India Company, it may be remarked, that little or rather nothing has been done by them for India for the true development of its resources; since easy means of internal communication—the very first step necessary to effect this object—have never been attempted until very recently indeed; and were the whole projected system of railways unconditionally undertaken by the Company, it would be but a tardy fulfilment of long-deferred obligations which their claim of seignorial dues on the land requires of them. That "property has its duties as well as its rights" is equally true in India as in Ireland; and quite irrespective of the political colour which was given to that aphorism. As has been observed by an eloquent writer in India, in a valuable but fugitive report, "Improvements "are the bounden duty of a government which claims the landlord's "right of property of soil, and leaves the great mass of the inhabi-"tants no higher objects of *amor patriæ*, or claims from that govern-"ment on their patriotism, than the limited gratitude of a rack-rent "tenantry: the doctrines of political economy, though true as mathe-"matical demonstrations, apply not in cases where the native ener-"gies of the people lie crushed under the most debasing of all "superstitions, and the most exhausting of all systems of taxation."

97. So sensible of the value of better and improved roads have been the best informed resident officers of the East India Company, that, a few years since, it was proposed by them that five per cent. of the revenue of the country should be appropriated to its general internal improvement; and the principle of such a measure was

fully admitted by the late Sir Robert Grant, the enlightened Governor of Bombay, who only so modified the idea as to suggest a smaller percentage. The establishment of a distinct Department for Roads in the Bombay Presidency about seven years ago, under a competent Engineer; the operations since conducted by him, to the aggregate amount of about £50,000 sterling; and the late suggested improvements in the navigation of the Nerbudda river, all prove that the principle, at least, of the East India Company attending to internal improvements is fully admitted, and was acted on; though it is to be lamented that courage has hitherto been wanting to carry this principle to a sufficient extent, or to mete out the full measure of justice due to the country, and to lead to a development, not only of its commercial and agricultural capabilities, but to effect its military security.

98. Taking one million as the annual amount for interest and sinking-fund to be charged on land revenue, in addition to the railway profits, surely the credit of the East India Company could raise in a few hours the necessary capital. This will practically be the same as one of the plans proposed for obtaining money to make railways in Ireland, of which the leading feature was to be an extension of the credit of the State to the counties, on the security of the local resources. Why not, therefore, at once raise the money by an Indian Railway Loan on Long Annuity Stock, secured on the land revenues of the particular districts of the country to be pervaded and benefited; or by many of the financial contrivances well known in the London Money-market? The security to the investors is undoubted; the risk to the undertakers nothing; the amount of immediate benefit, in an agricultural, commercial, fiscal, military, material, and, in short, every point of view, almost beyond bounds of expression.

99. India, under railway aspects, greatly resembles Ireland in many respects, and the weighty reasons adduced in favour of Irish lines seem to present themselves naturally to the mind while contemplating Indian railways; and the following arguments, hastily blended, are but the echo of what was written and urged in all quarters at the time in favour of operations in Ireland, and which come, happily, to hand and are easily applied, *mutato nomine*, to India:—

> "As far as one or two principal lines go," wrote the powerful pen of the Editor of the *Times*, "railroads are "perhaps the most useful mode in which public money could "be expended in *India*." "A nation," observes a writer in the *Athenæum*, "*may wisely spend money upon other considera-*

" *tions than those which govern a private capitalist.*" "We know " not, indeed, how the trading house of Great Britain & Co. " could lay out money to a greater advantage than by " bringing its *Indian* resources into full operation." *India* " is a farm in the worst possible condition; out of heart and " unprofitable. In such cases the wise man applies his " other resources in the work of amelioration; *he advances* " *his capital on the prospect of remote but certain returns.*" " Time does wonders: the Report" (on the *Irish* Railways) " will at least contribute to hurry on events, by the know- " ledge of the details which it will disseminate. In adding " the unit of our own convictions we do our duty as journal- " ists and ease our hearts as men. We repeat, then, that " the project of a grand and comprehensive system of rail- " ways for *India* is a godsend to the cause of humanity, of " peace, and of national prosperity."

100. The admirable section (of the Irish Railway Report) "*On the influence of Railways in developing the Resources of a Country,*" contains a multitude of statements calculated to inspire the firmest hopes of the success of those works in *India*:—

> "We have direct proofs" say the (*Irish* Railway) Commissioners, "that *India* is as capable as other countries of being " influenced by the same cause and of profiting by its ope- " ration;" and they add forcibly: "and there is this addi- " tional motive to recommend the subject for consideration, " that the backward state of the country presents *a stronger* " *obligation, as well as a wider scope* for improvement. Past " misgovernment and neglect have certainly left an ample " field for exertion in *India*; and decidedly the moral obli- " gation to commence the work of amelioration grows " stronger every hour."

101. And how inexpressibly applicable to India are the follow- extracts, also from the *Athenæum*:

> "From the prosperous results that have followed other " projects that have from time to time been undertaken, to " better the state of *India*, the fairest auguries are to be " drawn for the enterprise now recommended. In every " case where a new ordinary road has been opened through " districts before impervious, an increase of traffic and inter- " course has been the uniform consequence, by extending " the field of industry and contributing to the tranquillity " of the country, by opening and facilitating communication " through tracts where guilt and outrage had previously

"found secure asylums." "Results equally happy have "attended other undertakings, proving the aptitude of *India* "to profit by all the efforts of public or private enterprise, "to develop her resources and give her energies employ-"ment. The regular establishment of steam navigation "upon the principal rivers and along the coasts of *India* has "given to mercantile and general social activity a vast "impetus. Not only have old branches of trade been ex-"tended, *but nine-tenths of the traffic at present carried on is* "*new.* That a well-arranged system of railways would have "the effect of continuing and extending through the country "the advantages which the outports have thus obtained by "the introduction of steam-vessels seems to be indisputable. "In fact, in the present state of commerce *the railway is an* "*exigency of the country*—one of the principal wants of *India.* "Perhaps we might lay down a general proposition, and say "that *a railway is a corollary from a steam-ship.*

102. "Upon the moral effects of the extended intercourse "likely to take place between England and *India* in conse-"quence of increased facilities of travelling in the latter, "considerable stress is very properly laid. Most true it is, "and not more true than deplorable, that *India is very little* "*known to the British people;* nor can we imagine any better "means of promoting that most valuable of useful informa-"tion (in fact, it is self-knowledge) than the execution of a "great system of public works, forming an easy and rapid "mode of communication throughout the country. Bacon, "in the '*Advancement of Learning,*' interprets the texts in the "prophet Daniel, '*Many shall run to and fro, and knowledge* "'*be increased.*' Of the effects to be anticipated from the "progress of nautical adventure, and what he calls the "'openness and through passage of the world.' With how "much more force would this application of the prophetic "words have struck our great philosopher, had he seen the "steam-ship and the railway! *Multi pertransibunt!* may "well be exclaimed of these days of ours; and yet we see "but the infancy of these mighty instruments of civilization "and enlightenment. The steam-ship was the first bond of "real union, thorough and indissoluble. Most truly observed "the French Minister of Public Works, in a late address to "the Chamber of Deputies, 'Railways are, next to the in-"'vention of printing, the most powerful engine of civili-"'zation that the ingenuity of man has ever devised. It

" ' is difficult, if not impossible, to foresee and define the " ' results, which they must of necessity at some period pro- " ' duce on the fate of nations.' "

103. And another writer, acting on a different line of politics and principles, says :—

" We have no hesitation in expressing our decided and " deliberate opinion, that to a country circumstanced like " *India*, such an expenditure of the national funds should be " the first duty of the Government. The tolls upon the " principal *railroads* we have no doubt would abundantly " repay the expense of construction, and the indirect returns " to the Government in the general improvement of the re- " sources of the country, is incalculable. So far as these " principles go, we believe there can be no controversy or " even a difference of opinion. We can conceive, indeed, " no more noble enterprise for the British Government to " engage in than that of constructing railways through " *India* at the national expense. *We have ever believed the* " *great fault of all British Governments to have been a niggard-* " *liness of expenditure in undertakings like these ; and we say this* " *in the face of the many magnificent undertakings which even in* " *India have been accomplished by Government.*

104. " We hold that the best, because the most practical, " view is that which assumes, in the first instance, that the " construction of railways under any system, being a *good*, " we ought not from any foolish preference for either " Government interference or private enterprize, in the " present circumstances of *India*, to reject any feasible " prospect of *seeing that good accomplished*. But it is clearly " the duty of the Government, and the interest of the public, " that whenever private enterprize is willing to execute a " railway from one place to another, every facility should be " afforded by the State, unless Government are ready to " supersede its efforts by constructing the proposed railway " at the public expense."

105. On general principles, and as applied to free states, a Government ought not to interfere with any enterprize that might otherwise be entered into by associations of individuals ; but when, from the magnitude of the undertaking, private enterprize shrinks from the task, and when the Government is at the same time owners of the soil, it stands in the position of a simple proprietor. Or, even if that were not the case, Government aid should be extended when the condition of the country is such that in respect of

advancement—as regards the surface only—from a state of nature, as in *India*, it may be said scarcely to have gone a step, yet, having the population advanced considerably in all the arts and usages of civilization, imbued with skill and industry, but without capital.

106. In such cases, though a particular work may be executed by individual enterprize, a great system of internal improvements such as the railways contemplated, might be best effected by the State. Rules laid down in this respect for England are not applicable to *India*. England is chiefly engaged in mineral, manufacturing, and commercial pursuits; and those who follow agriculture generally do so on a large scale, and on scientific principles, so that the productive effort of the well-fed skillful labourer, on a soil of a much inferior quality, is greatly more than what it is in *India*, where the largest body of the population have scarcely any employment but agriculture, followed, not as a pursuit based on capital and executed with skill, but as the means of procuring to its inhabitants this stinted daily allowance of food of the most inferior kinds; and whereby—it may be added—from the peculiarity of the climate and seasons, and, above all, from the want of any sort of economical means of transport, the wretched people are often scourged by famine.

107. The preceding are the substance of some arguments in the *Dublin Review* in reference to railways in Ireland, and the same writer says:—

> " The advancement of England to its present state of
> " improvement by the energies of individuals, and the
> " combined skill and pecuniary resources of associated bodies
> " of capitalists, is the aggregate result of the labour of two
> " centuries."

In several of the American states, particularly that of New York, they have been advanced vastly in the scale of national importance and prosperity—too often, alas, from the outlay of unrepaid English capital—by the creation of numerous links of intercommunication—chiefly, however, under the direction of the state governments—effecting for that country within five and twenty years a development of resources unparalleled in the history of interior ameliorations; a result which can only be compared to—what may certainly be predicted—the consequences of the improvement of *India*, an example which our Government have followed in Canada by the construction of the Rideau Canal, and which must be followed out in India by the adoption of the railway system if the Government wish to advance—at a pace equivalent to the movement on those lines—the improvement of these fertile districts, instead of allowing them to crawl, walk, ride, wagon, canal, and coach themselves through centuries of difficulties, to that stage of improvement to which they might at once attain, almost by a stride, by proper aid from the Government, indirect, at least, if not more decisively, extensively, wisely, and directly afforded:

> "Since" (to repeat the most expressive language of the Irish Railway Commissioners, and here applied to *India*) "it "is a waste of the public available resources to suffer a large "portion of the empire to lie fallow, *or to leave it to struggle,* "*by slow advances and with defective means*, towards im-"provement, when the judicious aid of the State might at "once make it a source of common strength and advantage."

108. In the words of a writer in one of the quarterly periodicals:—

> "*When society would derive a vast benefit from any public* "*work*, which private interest might not consider a suffi-"ciently tempting speculation, or might not possess the "means of accomplishing, we hold it to be the part of "Government, which represents the general interest, to be "the undertaker. We apprehend this has been the case of "*India* for many a day, and we have already shown that the "community have profited most amply by the little in the "way of public works which the Government have effected "in that country."

109. Ten or eleven years ago a Select Committee of the House of Commons, in considering the post-office communications, thus reported:—

> "Every new communication which shall be opened will "open new districts for the employment of capital and the "increase of industry; a new market for the manufacturer, "a new supply of food for the artisan, and a new source of "revenue for the State. Every improvement of lines of "communication will tend to induce the capitalist to settle "in the more remote parts of *India*, and thus spread industry "and happiness in those hitherto neglected districts; civili-"zation and employment will extend; and disturbance, and "the cost of putting down disturbance, will be got rid of. "The Government should recollect that it is peculiarly an "English object, that the most remote parts of *India* should "be connected as intimately and as closely as possible with "herself, that this object will be mainly effected by opening "to every part of that country the most direct and easy lines "of communication with England."

110. And an eloquent anonymous writer on the same subject says :—

" Facilitate the intercourse between the two countries; " connect not only *India* generally, but also her *remote parts*, " as intimately as possible with England, and without in " reality changing the distance of places, we shall in effect " bring all not merely within the influence of each other, " but within the influence of the executive; giving to each " the advantages of both; compressing the whole of the " countries, as it were, within the circuit of a few *days*. We " shall thus introduce into *India*, not only the muscle but " the *mind*, the *enterprize*, and the *security* of England; im- " parting to her new life, new feelings, new objects, and " new interests. Ingenuity and capital will have an *un-* " *disturbed* and peaceable scope to improve where Nature has " been so superabundantly beneficial; agriculture will ad- " vance, manufactures flourish, science employ her genius, " and talent, industry, happiness, and civilization extend. " Railways and steam are indeed effecting a new econo- " mization of life, of business, of government, which neither " ignorance can stop nor interest interrupt; they will be the " great degenerating powers of *India*. The more the case " is considered, do advantages, benefits, conveniences, and " accommodations multiply. It opens to *India*, as it were, a " new world, and discloses her resources to the enterprise " and public spirit of England."

111. And in his evidence before the committee of 1835 on public works, the writer of this report said :—

" All experience shows that any expenditure of money on " public works had invariably introduced comfort and peace " to the labouring population, and had increased the public " revenues in direct proportion to the amount of money ex- " pended. Of such public works railways stand first, pre- " senting *the mode of communicating by land with steam* which " by sea and by river has been so beneficial to *India*. Rail- " ways possess extraordinary claims on the Government from " their efficiency as instruments of agriculture, commerce, " and military defence, and as conducive to prosperity, " wealth, and peace; claims more apparently paramount as " regards *India*."

112. After so many quotations from various writers on a subject so analogous, indeed (almost) so identical with that of railways in India, it must not be considered supererogatory to conclude with a

few direct extracts from the second Report of the Irish Railway Commissioners, bearing forcibly and remarkably on the introduction of a general railway system into any country; and the most casual perusal cannot fail to impress the reader with the curious and extreme applicability of the carefully digested remarks of the distinguished authors of that valuable document to the object propounded in this statement:—

> 113. "Experience," say the Commissioners, "testifies that "increased facilities of intercourse between distant places, "and *more especially between sea-ports and the interior of a* "*country*, are among the most effective means of extending "civilization with its attendant lights and benefits. *Together* "*with the opportunities of communication, a desire to take advan-* "*tage of them is diffused*, and the important results to be "expected will follow more promptly, in proportion as the "means thus presented shall combine security with con- "venience and despatch with both. The proofs and in- "stances which sustain this assertion are not confined to "the case of any one country or district, although they are "more observable in communities where the resources of "wealth and commerce already possessed by the inhabitants "made them to turn every advantage as it arises to imme- "diate account."
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> 114. "In countries less forward the ability to profit by "the occasion does not at first exist, especially among the "lower class, but must be acquired by degrees; consequently "improvement also will be *gradual*, and though more tardy "in its first manifestations, is not eventually the less certain "and striking. The extent to which intercourse is not "merely promoted, but actually *created*, by the facility of "accomplishing it would, however, be scarcely credited, but "for the numerous and authentic examples which establish "the fact."

After quoting many very remarkable examples of increase, particularly that in Belgium, which has been *twenty-fold*, and commenting on the extraordinary traffic of passengers moving very short distances at the lowest fares, a fact is stated which seems peculiarly applicable to India:—

> "When the Erie Canal in America was commenced, there "were not, over its vast extent of many hundred miles, more "than fifty small villages within a distance of twenty miles "on each side, whereas, ten years after its completion, there "were one hundred and thirty villages exhibiting daily

" residence of prosperity and wealth, besides numerous and " well-cultivated and well-stocked farms."

115. Having alluded to the American railways, it is stated, from official documents, " that the railways completed in the United States up to the 1st January, 1835, extended 1,600 miles in length, and their cost was £8,130,000 sterling;" being only about £5,000 per mile. One of the most expensive lines, as has been previously stated and analysed, having little exceeded £8,000 per mile, which sum has been assumed herein as the average of the cost of railways throughout India.

116. " A well-arranged system of railways" (the quotation is again from the Commissioners' Report), " would " have the effect of continuing and extending throughout " the country the benefits which the outports and river " towns have obtained by the introduction of steamboats. " It is scarcely necessary to dwell upon the great and " obvious advantages that would result from such combined " facilities of intercourse. The subsisting relations of " business and commerce would be thereby extended and " enlarged, and others formed, opening fresh resources to " the industry and enterprise of the trading portions of " the community, while an object of no less consideration " would be immediately attained in rendering agricultural " produce the great staple of the country, at the same time " more profitable to the producers, and accessible on easier " terms to the principal purchasers and consumers. An " opinion, which we believe to be quite erroneous, has become " prevalent, that because in populous and wealthy districts " in which railways have been established, their traffic has " consisted for the most part in the conveyance of passengers " and goods of high value, they are therefore ill-adapted " to the conveyance of goods of bulk or of ordinary value. " We cannot, however, see any reason to doubt, but, on the " contrary, we can see good grounds for calculating on a " great extent of profitable traffic in agricultural produce " as well as in other articles.

117. " It would be an endless task to point out the " various interests and social relations which would be " more or less affected by the introduction of this mode of " traffic on an extensive scale; but it is very proper, " before we conclude this point of our subject, to advert " shortly to its probable effects upon some departments of " the public service. Of these the post office naturally

" first presents itself to the mind. The vast importance " of the transmission of letters needs but to be mentioned. " There is not a merchant or man of business who cannot " readily appeal to instances of the great value of even a " few hours saved. We may contemplate as another " example the effects on the military service of the country; " the facilitating of the moving of troops in large bodies " over hundreds of miles in a few hours, fully supplied with " artillery and stores, and in a state of perfect readiness " either to oppose foreign aggression or repress domestic " outrage, must be apparent, and its influence can scarcely be " overrated. But it is needless to multiply instances of " the application of this principle, as far as its powers have " been ascertained, to the actual concerns of the country, " and it would be folly to attempt to impose limits to its " future influence in creating new resources for its popula-" tion or in giving directions, as yet unknown, to those " already possessed. The mind can scarcely set bounds " to the extent to which the effects of so important a dis-" covery may be carried, nor the imagination take too wide " a scope in speculating on its future operations. What " has been already done upon its very threshold, and, as it " were, in the dark, seems but an earnest of advantages to " come when experience shall have shed its full light upon " the subject and brought this wondrous power still more " within the grasp and command of man."

118. And it is desirable to state on the authority of the Irish Railway Commissioners :—

" *That it would completely frustrate most important objects, and* " *oppose a bar to future improvement, if those portions of railway* " *lines which hold out special objects of advantage are alone* " *undertaken or monopolized by isolated companies*—such, for " example, as the first sectioning out of the great towns" [Bombay, Calcutta, &c.] " over which all the traffic with " other places, near as well as remote, must of necessity pass, " *for it is manifest that if the best and most productive portions* " *are taken possession of unconditionally, there can be no reason-* " *able hope that the remainder will ever be carried into effect.* " *It would be even more advantageous that no part of the line* " *should be sanctioned until the country should possess within* " *itself the means of undertaking the whole system to its full* " *extent, than at once and for ever to obstruct and paralyze all* " *future exertions for its accomplishment by abandoning the* "*portions having particular and distinct interests*, the monopoly "of some of its most productive detached portions. *It is* "*essential for producing the greatest national advantages that* "*the gain on the more profitable parts should be available to bear* "*the loss of others of deficient revenue;* provided only that in "the whole a fair remuneration for the capital invested can "be derived from the undertaking."

119. It will be manifest how importantly this principle, which has already been propounded in an antecedent part of this statement, bears on the enforcement of the railway as an entire and comprehensive measure as between the two capitals of Bombay and Calcutta, and that notwithstanding its greater length and cost, it must, in addition to being free from many of the objections to which the Masulipatam line is liable, be, from the very fact of the number of large places of great local traffic embraced, much more likely to be remunerative. Still, even with this aid, and with the advantages of pervading the great coal and iron fields, it is obvious that over many districts, and those probably when the cost of construction would be greatest, the traffic would be least. Consequently, to insure the great fruits of a perfect communication across India, such a connection with the great chain of correspondence and intercourse between Great Britain and China, one line of railway must be formed at all events, *in its entirety*, and thus combine the most important advantage, which cannot be too often reiterated, *of making the profitable portions pay for those which are less so*, thereby insuring the benefits of the railway to those remote and central districts, when, in the words of a fellow-labourer on those subjects, "if the pecuniary returns may not be so great, other results may be looked for well calculated to afford the highest gratification to the enlightened legislator and statesman."

120. In reference to the natural and inevitable variation in the amount of traffic over various parts of the railway between the extremities, it may not be irrelevant to observe that, in treating in a previous page on the number of trains daily, it was not intended to intimate, nor must it be assumed, that six or any other given number should necessarily pass daily over any *whole line*, as from Bombay to Calcutta, to produce a given amount of traffic, but that such extent of duty might be performed as an aggregate and not exceed the assumed expense. On some divisions of this line, five, six, or a dozen trains may leave each end per day, while in others, two, or even only one, might be required, but it is impossible in this stage of the inquiry to enter into such detail,

nor is it necessary so long as the average rate of expense per train mile over long distances, and under all circumstances, is known and can be depended on, which the facts previously brought forward demonstrate most fully.

121. Great, however, as the advantages of the contemplated railway would be to all parts of India, it is of the most vital importance to the Bengal districts, possessing as they do the largest amount of trade, carrying on the greatest extent of correspondence, and having occasion for the most frequent extent of personal intercourse with Europe and with the principal stations in India. So impressed have the community of Calcutta been with the high importance of a better connection with the mother country, that for twenty years nearly they have been supplicating for an improved communication, and especially for a direct steamship intercourse from the Red Sea to the Hooghly: liberal subscriptions to the amount of nearly £20,000 have been made—without the slightest hope of return, but merely to forward this object generally by giving a command of funds for negotiation and investigations—and to this fund native princes, merchants, and inhabitants freely and liberally contributed in common with English subjects. Is it not, then, to be expected that they will hail with acclamation a proposal that will place them within two days' distance of Bombay, and at the same time open an economical channel of communication with the interior for all the purposes of interchange of native produce and imported manufactures?

122. Nor will the English merchants of Bombay and the intelligent and wealthy Parsee traders be backward in supporting a measure securing to their port the inland traffic, which imperfect roads are driving away to a much more distant market. If, in short, the advantage of a steam connection between the Red Sea and Calcutta direct were so great as to elicit the expression from Lord William Bentinck, when Governor-General of India, "that it "would be cheaply bought at any price," although it would have left Calcutta still fourteen days farther from England than Bombay, what may not be expected from the opinion, support, and exertion of that community to a place which will practically place them on an equal footing in that respect? If the eloquent passages which are extracted below from the manifesto of the committees appointed to forward the steamboat arrangement were called forth in support of the Calcutta petitioners, the pen of the talented writer would be still more ready to support so satisfactory and complete an arrangement as now contemplated:—

124. "To India," says that writer, "England is indebted

"for wealth, for fame, and in some degree for the prominent "station she holds among the nations of the world. In "return, she has a duty to perform to the countless millions "subject to her sway—a duty which can never be performed "as it ought to be until the barrier which upholds their "mutual ignorance, and thence fosters their mutual preju- "dices, is broken down. That barrier once removed, can it "be for one moment doubted that the arts, the science, the "civilisation, the capital of England would rapidly find "their way to India? Their very nature is to extend. "They only require a road, and when that is made easy to "any place needing their presence they cannot but go. "India does need these, and England can furnish them, and "it is her duty to do so.

125. "It is her bounden duty to open wide the doors of "India for the entry and spread, *emphatically*, of the know- "ledge of Europe. It is the one thing needed in India to "enable her to advance, as, *under the dominion of England*, "she ought to do, in the scale of nations, and this can only "be done by approximating the two countries in the manner "proposed. Among the advantages to England would be "the more ready employment of capital, with consequent "extension in commerce, and the greater security of the "Indian empire, and numerous other similar benefits more "and more apparent to those who have paid attention to "the subject; and nothing would appear to be wanting to "insure a communication being established, as it ought to "be, on the most enlarged and perfect scale, but a similar "general expression of the public desire of the British "Islands, as has now been long declared through all parts "of India."

126. It is now time to draw this long Paper to a close, though not without expressing a hope that what has been adduced may lead those for whom it is intended to take some further steps in the inquiry, and afford another opportunity for going into and discussing the points of railway construction and working, estimates, returns, &c., and a variety of details generally, which it has been impossible to attempt at present. The maps hereto attached have been compiled with the kind aid of John Walker, Esq., Geographer to the East India Company, to whom the best acknowledgments are due for his extreme attention and valuable assistance. The general points herein mentioned are marked on Allen's Map of India, and the chart of the route between England

and China will elucidate the subject of the distances on the line of steam-ship transit.

127. Very great attention has been experienced from the officer of the East India Company's Library and Museum, and from the librarians of the Asiatic and Geological Societies. Professor Royle afforded the loan of some valuable reports and pamphlets; and it is only due to that eminent naturalist to refer to his invaluable work on the 'Productive Resources of India' as a fount from whence much information has been drawn, and which should be studied by all interested in the advancement of India.

128. In conclusion, it may be remarked that the great object herein has been to broach the leading principles, to analyse the principal features only of this subject, and to draw the attention of those interested, and who have originated the inquiry, to the consideration of the proper aspect in which this absorbing question, so pregnant with beneficial results to India and to Great Britain, should be considered; for, as has been observed elsewhere of the advancement of similar works for Ireland, it may as emphatically be said here:—

> "Few objects of ambition would be more honourable than "that of being instrumental in promoting a general and "comprehensive system of internal communication by rail- "way through so important a portion of the empire as "*British India.*"

(Signed) Charles B. Vignoles, F.R.S.
Civil Engineer.

(*Dated*)
London, September 22nd, 1842.

[III.—Additional Memoranda

III.—Additional Memoranda as to the Swedish Railway System, by Mr. C. P. Sandberg, Assoc. Inst. C.E.

In order to show the extent of the development of the Swedish railway system from a technical point of view, the tables annexed have been drawn up. They are divided into Tables I., II., and III., and some of the figures therein are taken from official sources, such as the recently published 'Nordisk Jernbane-Kalender.'

Table I. shows the cost, gauge, and speed of the lines open for traffic, the weight of rail per yard in use, the working results for 1871, and finally the working conditions. Table II. deals with the cost, gauge, and speed of the lines actually in construction. Many new schemes are proposed, companies are in course of formation, and concessions are granted to carry out some of the projects; but they are not included in the table.

Several of the details are wanting with respect to the lines mentioned in Table II., but the results given are sufficiently numerous to arrive at a practical conclusion with regard to each kind of gauge and construction.

An abstract of the two foregoing tables is given in Table III., which may now be more particularly analysed. The railways in Sweden are divided into two classes, those of 4 ft. 8½ in. and those of a narrower gauge. The railways of the standard gauge are again subdivided into two classes, namely, those of heavy and of light construction. The narrow-gauge railways are divided into four classes, according to their widths, namely, 4 ft., 3 ft. 6 in., 3 ft., and 2 ft. 6 in.

The total lines open to the end of last year, with their average cost per mile as well as their mileage, as derived from Table I., are arranged for comparison with the speeds indicated at the head of the columns. These speeds are obtained by taking the averages recorded in the time-tables, and 50 per cent. is added to obtain a maximum, making allowances for delays, for working at lower speeds than average on up-hill gradients, on curves, and at the stations. Similar figures are given for some of the lines in course of construction, assuming the speeds at which the trains are proposed to be worked, and taking the cost as estimated. Next follows the total mileage of the two classes taken together at a mean cost per mile, from which it will be seen that there are nearly 2,000 miles of standard gauge open and in construction, as compared with about 400 miles of narrow gauge, or out of 2,400 miles of railways there are only 17 per cent. narrow-gauge lines as against 83 per cent. of broad gauge. Of these 17 per cent. 5 per cent. are unconnected, and 12 per cent. connected with the main system. The unconnected lines consist of nine separate short pieces in different parts of the country, 115 miles in all, principally used for mineral and timber traffic between lakes and mines, where sledging was formerly employed in the winter.

Thus the total mileage, when completed, of the 12 per cent. of connected narrow-gauge lines will be 258 miles, divided between eight branch lines. But at present there are only 82 miles open, and hence there is only one instance of break of gauge in all Sweden, namely, at Herrljunga.

As regards this solitary example of break of gauge from 4 ft. to 4 ft. 8½ in., the line in question has been working about ten years, and the experience derived from it must have greatly influenced the decision in respect to the construction of other railways connected with the main lines, so much so that in the history of nearly all the branch lines we find that after subscribing capital for the first estimated cost of a 3 ft. or 3 ft. 6 in. narrow-gauge line, the next proceeding has been, in nearly all instances, to consider whether the gauge should not be changed to 4 ft. 8½ in.; and in most cases there has been an augmentation of capital to meet the difference in cost in maintaining the standard gauge. This was only a few weeks ago the case with the Malmö-Ystad line. In one instance, the Norberg line—constructed about ten years ago—a widening to the standard gauge is now going on to meet the approaching main line.[1]

However, there are instances where there is no more capital available, where railway communication is a necessity, and where the expected traffic is so small that it would hardly pay even for a narrow-gauge line. Of this class there are six lines, averaging 20 miles each in length, which may be termed feeders to the main line, cheaply constructed for low speed and light agricultural traffic. The comparison between the relative mileage of the broad and narrow gauge lines shows that the narrow-gauge idea has of late met with very little encouragement in Sweden.

In comparing the cost of the standard-gauge lines of heavy and light construction with the cost of the narrow-gauge lines, it is essential to include the speed as a most important factor, for unless that is done when comparing the cost of the standard gauge of heavy construction with that of the narrow gauge, the advantage is all on the side of the latter, but taking the speed in as a factor of the cost of making a line it seems to be more deserving of consideration than even the gauge.

The Swedish State lines, costing nearly £7,000 per mile, running at a maximum speed of 37 miles per hour, taken with the light lines of standard gauge at £4,000 a mile, with a speed of 23 miles per hour, give an average cost of standard-gauge lines amounting to about £6,000 per mile, capable of a general maximum speed of 33 miles.

Against this the narrow-gauge lines of different widths constructed at an average cost of £2,900 a mile, are capable of a maximum speed of, say, 15 miles per hour; but the reason why they are so much cheaper is that many of them are not adapted to passenger, but only for mineral and timber traffic. Finally, the two are set side by side in the table, so as to compare cost, speed, and gauge. It will be seen at once that the cost is nearly in direct proportion of the speed whatever may be the gauge, and of those comparing most favourably are the light standard gauge and the 3 ft. 6 in. gauge, which have an advance 4 per cent. of speed over that of cost, whereas the 4 ft. gauge has just so much less speed as compared with its cost. Singularly enough, besides the 628 miles of heavy lines of standard gauge now in construction, the two kinds of railways most in vogue in Sweden at the present time are the 400 miles of the light standard gauge, and the 88 miles of 3 ft. 6 in., but none of 4 ft.

In conclusion, as far as the practice on the Swedish railways goes, it must be first stated that the information given in the tables is put down as nearly as can be ascertained, and as fairly as possible. It is manifest that the figures are liable to modification, especially with regard to lines in construction, but they are given as estimated and in accordance with practice already obtained, and for the sole purpose of technical comparison. These results depending in great measure on local circumstances in Sweden may not be applicable to other countries except on similar conditions. There is of course nothing to prevent a higher speed

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[1] Since the above was written the Swedish mail brings news of a contemplated widening of the 3 ft. 6 in.-gauge Sundsvall-Torpshammar line, in view of the approaching extension of State lines in that direction. This line, after careful consideration in Parliament, is to be constructed as a 'light railway' on the 4 ft. 8½ in. gauge.

being adopted on narrow-gauge railways than what is run on those in Sweden, but in such case they must be constructed for the purpose, with more favourable gradients and curves, with stronger permanent way and rolling stock, and at a consequently increased cost. So much so, that the conclusion Mr. Elworth, the Director of the State lines in Sweden, arrived at three years ago. as to the difference in cost between narrow gauge and broad gauge for the same kind of work done, seems to guide railway construction in Sweden even now, at least judging from the tables.

The cost of translading of goods and passengers, and the delay and inconvenience caused thereby, is unimportant when compared to the loss of time incurred by traveling over long distances at a low speed, but it should not be lost sight of where time is of value. In Sweden, with the standard gauge already established to a great extent, a cheaper and lighter construction seems to be preferred to break of gauge. This is at least the case with some of the private companies who cannot afford to copy the heavy system of broad gauge, of which the Government railways are the type.

As there are a great many opponents to the construction of light standard-gauge lines, worked in connection with the heavy ones, owing to the apprehended destruction of the lighter rails in case the engines in use on the heavily-constructed lines should run over them, the following calculations may possibly serve to obviate some of their objections :—

In the instance of the Swedish State lines, with rails weighing 66 lb. per yard, and a 27-ton engine running at 37 miles per hour, the maximum effect on the rail may be taken as $37 \times 27 = 999$.

In the case of a line of standard gauge of light construction with rails weighing 50 lb. per yard, as used on some of the joining lines, we have $66 : 50 :: 999 : 756$ and $\frac{756}{27} = 28$ miles per hour, as the proportionate maximum speed for the lighter rail, so far as safety is concerned. As, however, there are also other effects of the heavy engine, such as crushing the rail-head, and bending the rail, the load on each driver must in no case exceed one-half and two-thirds of what the rail and rail joint will carry without taking a permanent set. It is clear that the reduction of the speed cannot compensate for too great a disproportion in the weight of the engine as compared with that of the permanent way; but on the other hand it is obvious that where the difference is not too great, the lowering of the speed will overcome the difficulty of absolutely limiting the rolling stock to its respective road. In case of emergency, such as war, a somewhat heavier rolling stock could very well be used without risk, although it is quite right that each road should, as far as possible, be worked by rolling stock suited to it. In giving these weights of rails, it need scarcely be said that their efficiency does not depend solely upon the weight, but also upon the form of section and the quality, inasmuch as a 50 lb. rail of modern section and good quality will do the work of a 66 lb. section if of extravagant form and poor quality. Although Sweden can show a few cheap narrow-gauge lines, the light construction of the broad gauge is preferred from sufficiently long experience of their relative value. The reason seems to lie in the warning presented by the solitary example of break of gauge, coupled with the already firm establishment of the standard gauge in the country, and not from any disbelief in the efficiency of the narrow gauge, judged by itself, for countries where there is no standard gauge system already constructed.

TABLES I., II., AND III.

TABLE I.—COST, GAUGE, AND SPEED

Name of Line.	Mileage.	Weight of Rail, lbs. per Yard.	Total Cost of Construction per English Mile. (Single Line) 4 ft. 8½ in. Gauge.	4 ft. 8½ in. Gauge.	4 ft. 0 in. Gauge.	3 ft. 6 in. Gauge.	2 ft. 6 in. Gauge.
		lbs.	£	£	£	£	£
State Lines	692	66	7,450	Standard Gauge, Heavy Construction.			
Royal Swedish . . .	54	66	6,311				
Gefle-Dala	57	60	6,817				
Total	803	Miles at £7,328.					
Ystad-Eslof	47	50	..	4,477	Standard Gauge, Light Construction.		
Landscrona - Helsingborg-Eslof . . .	37	50	..	4,778			
Kristianstad - Hessleholm	18	50	..	4,730			
Wexiö-Alfvesta . . .	11	50	..	3,784			
Marma Sandarde . .	6	44	..	5,584			
Total	119	Miles at	..	£4,603			
Boras-Herrljunga . .	25	46	Connected with Standard Gauge Lines.		4,517	Narrow Gauge.	
Uddevalla-Wenersborg-Herrljunga . . .	57	43			4,675		
Wessman Barken . .	11	40			4,094		
Norberg	10	44			3,517		
Söderhamn	9	40			5,030		
Hudiksvall	7	45			3,800		
Total	119	Miles	at ..	.. £	4,466		
Köping-Uttersberg . .	22	34	Unconnected Lines.		..	1,960	..
Kristinehamn-Sjöändan	7	25			..	3,428	..
Fryksta	4	25			..	2,370	..
Total	33	Miles at ..		..	.. £	2,322	
Kroppa	6	18	Miles at	..	..	.. £	1,440

OF LINES OPEN FOR TRAFFIC IN SWEDEN.

Working Results for 1871.			Working Conditions.			
Gross Receipts per Mile.	Proportion of Working Expenses to gross Receipts.	Net Profit on Cost of Construction.	Open for Traffic. Years.	Speed Worked to. Maximum.	Speed Worked to. Average.	Description of Traffic.
£	per cent.	per cent.	medium.	miles per hour.		
616	50·2	3·7	10	39	26	Mixed.
508	56·8	3·4	17	24	16	Mineral.
1,449	42·3	12 1	14	22	15	Timber.
			Speed	37	25	
310	50·0	3·1	7	22	15	Agricultural.
498	50·1	5·1	8	24	16	,,
414	44·8	4·8	8	18	12	,,
381	54·9	4·2	8	24	16	,,
1,222	38·2	12·8	10	18	12	,,
			Speed	23	16	
327	41·4	4·2	10	26	17	,,
338	50·2	3·5	8	24	16	,,
424	50·4	5·0	13	15	10	Mineral.
477	40·1	8·0	17	21	14	,,
1,014	58·7	8·8	12	15	10	Timber.
650	48·3	8·7	13	15	10	,,
			Speed	22	14	
216	56·4	4·7	7	17	11	Mineral.
546	42·5	8·7	17	12	8	,,
509	35·0	13·8	22	12	8	,,
			Speed	15	10	
427	24·5	22·2	19	8	5	Mineral.

TABLE II.—COST, GAUGE, AND SPEED PROPOSED FOR LINES IN CONSTRUCTION IN SWEDEN

NAME OF RAILWAY.	Mileage.	Weight of Rail. lbs. per Yard.	Total Cost per English Mile (Single Line). 4 ft. 8½ in. Gauge.	4 ft. 8½ in. Gauge.	3 ft. 6 in. Gauge.	3 ft. Gauge.	2 ft. 6 in. Gauge.	Description of expected Traffic.
		lbs.	£					
State Lines . . .	162	66	7,000	..	..	..	..	Mixed.
Bergslagernas (Fahlun Kihl) . . .	123	64	7,000	..	..	..	..	Mineral and timber.
Halmstad Jönköping	97	..	4,639	Standard gauge, heavy construction, suited to a maximum speed of 37 miles per hour.				Timber.
Halsberg - Motala-Mjölby . . .	58	57	..					Mineral and timber.
Frövi-Ludvika . .	58	60	..					,, ,,
Stockholm-Westeras	117	56	..	..	..	..	..	,, ,,
Krylbo-Norberg. .	11	57	4,886	Widened from 4 ft. to 4 ft. 8½ in.				,, ,,
Total	626							
Average cost of 393 miles £6,358 per mile.								
Nyköping-Mölnbo .	32	..	..	3,160	..	..	..	Timber.
Nassjö Oscarshamn.	90	45	..	..	..	..	..	,,
Carlscrona-Wexio .	69	50	..	4,048	Standard gauge, light construction, suited to a maximum speed of 23 miles per hour.			,,
Upsala-Gefle . .	68	45	..	..				,,
Helsingborg Hesslcholm	47	45	..	3,907				Coal.
Kalmar-Emmeboda.	35	45	..	3,800				Timber.
Nora-Carlskoga . .	34	45	..	..	..	..	..	Mineral and timber.
Nynäsbanan . . .	25	36	..	..	..	..	..	Mixed.
Total	400							
Average cost of 183 miles .. £3,809 per mile.								
Sundsvall - Torpshammar . . .	39	45	..	..	3,134	Speed, say 15 miles per hour.		Timber.
Carlshamn - Wieslanda	49	36	..	..	2,154			,,
Total	88	miles	at	..	£2,588 per mile.			
Palsboda-Finspong.	34	30	Narrow Gauge.		Speed, say 10 miles per hour.	2,287	..	Mineral and timber.
Ulricehamn - Wartofta	23	25				1,304	..	Agricultural.
Total	57	miles	at	..	..	£1,904 per mile.		
Wikern-Mockeln .	21	25	..	..	..	..	1,754	Mineral.
Hjo-Stenstorp . .	19	..	..	..	Speed, say, 8 miles per hour.		1,754	Agricultural.
Lidköping - Skara-Stenstorp . . .	30	..	..	..	..	..	1,759	,,
Total	70	miles	at	..	..	..	£1,756 per mile.	

Table III.—Cost, Gauge, and Speed Compared of Railways in Sweden.

Standard, 4 ft. $8\frac{1}{2}$ in. Gauge.		Narrow Gauge.			
Heavy Construction. Maximum Speed worked to 37 Miles per Hour.	Light Construction. Maximum Speed worked to 23 Miles per Hour.	4 ft. Maximum Speed worked to 22 Miles per Hour.	3 ft. 6 in. Maximum Speed worked to 15 Miles per Hour.	3 ft. Maximum Speed to be worked to 10 Miles per Hour.	2 ft. 6 in. Maximum Speed worked to 8 Miles per Hour.
LINES OPEN.					
miles 803 at £7,328	miles 119 at £4,603	miles 119 at £4,466	miles 33 at £2,322	..	miles 6 at £1,440
LINES IN CONSTRUCTION.					
miles 626 at £6,358	miles 400 at £3,809	..	miles 88 at £2,588	miles 57 at £1,904	miles 70 at £1,756
TOTAL MILES AT MEDIUM COST.					
miles 1,429 at £6,903	miles 519 at £3,991	miles 119 at £4,466	miles 121 at £2,515	miles 57 at £1,904	miles 76 at £1,731
Standard Gauge.		Narrow Gauge.			
1,948 miles at £6,127 per mile.		373 miles at £2,884 per mile.			
Worked at speed of 33 miles per hour.		Worked at speed of 15 miles per hour.			
COST COMPARED WITH SPEED PER CENT.					
Cost, 100 per ct.	58 per cent.	64 per cent.	36 per cent.	27 per cent.	25 per cent.
Speed, 100 ,,	62 ,,	60 ,,	40 ,,	27 ,,	22 ,,

Note.—Cost, 100 per cent. ≐ £6,903 per mile.

Speed, 100 per cent. = 37 miles per hour.

IV.—Additional Memoranda as to the Denver and Rio Grande railway, by Mr. George Allan, M. Inst. C.E.

The following particulars of the Denver and Rio Grande Road can be relied upon as correct:—

Its track bed is from 10 ft. to 12 ft. wide, and is laid with sleepers of Rocky Mountain pine 6 in. by 5 in., 6 ft. long, and 2 ft. apart centre to centre.

The rails are of the Vignoles section, 30 lbs. to the yard, fish jointed, and in 24 ft. lengths.

The road is as well ballasted as any first-class American road, as, for instance, the Pennsylvania Central.

The passenger engines have 40 inch drivers, 4 wheels coupled, and a pair of small leading wheels; cylinders 9 in. by 16 in., weight on drivers 20,000 lbs., and total weight 25,000 lbs.

The freight engines have 36 inch drivers, 6 wheels coupled, and a pair of small leading wheels; cylinders 11 in. by 16 in., weight on drivers 30,000 lbs.; total weight 35,000 lbs.

Both classes are of the Pennsylvania Central Company's pattern, and each has a 4 wheel tender, weighing without coal and water 6,000 lbs.

All the carriages, or cars as they are called, are built on the bogie system.

The day cars are fitted up with two seats on one side and one seat on the other side of a central passage, and some are arranged somewhat after the fashion of Pullman's celebrated dining-room cars, with seats for one passenger on each side of the passage, or for two passengers at each table. The dimensions of the passenger cars are as follows:—

Length of platform	40 ft.
Ditto of body	35 ,,
Width of body outside	7 ,,
Ditto inside	$6\frac{1}{2}$,,
Height inside to centre of dome	$7\frac{1}{2}$,,
Ditto above rail to floor beams	$2\frac{1}{4}$,,
Ditto above rail to top of dome	$10\frac{1}{2}$,,
Ditto of centre of gravity above rail	3 ft. 2 in.
Angle of stability	$50\frac{1}{2}°$

Each car seats 36 passengers and has two water-closets. The bogies have each 4 wheels of 24 in. diameter. The total weight of a car is 15,000 lbs.

The freight stock consists of:—

	Weight.	Capacity.
4 wheel platform trucks	4,000 lbs.	10,000 lbs.
4 wheel high-sided trucks	3,500 ,,	10,500 ,,
4 wheel covered trucks	4,500 ,,	9,500 ,,
Bogie platform trucks	6,250 ,,	20,000 ,,

The bogie covered wagons are of the following dimensions, &c.:—

	ft.	in.
Length over the frame	23 ft.	7 in.
Ditto of body	22	1
Width of body outside	6	2
Ditto of body inside	6	
Height of floor above rail	2	4
Height inside	6	
Diameter of bogie wheels	20 in.	

Angle of stability when empty	56°
Ditto when loaded with wheat	51°
Floor area	132 square ft.
Space in box	792 cubic ft.
Weight	8,800 lbs.
Capacity	17,600 lbs.

The cattle cars are mounted on 4 wheel bogie trucks, with bodies 24 ft. long, by 6 ft. wide inside, their weight is 8,000 lbs. They carry each 9 head of cattle, whilst the cars on the 4 ft. 8½ in. gauge are 28 ft. long, weigh 18,000 lbs. to 20,000 lbs., and carry 14 head of cattle; the saving being 397 lbs. of dead weight per head in favour of the narrow gauge.

V.—Additional Memoranda as to the Goods Traffic conveyed over the Bombay, Baroda, and Central India railway, during the years 1870 and 1871, &c., by Lieut.-Colonel J. Pitt Kennedy, M. Inst. C.E.

The following Table gives a classification of the goods traffic conveyed over the Bombay, Baroda and Central India railway, 312 miles in extent, during the years 1870 and 1871. Columns 1 and 2 show 43 varieties of goods conveyed. Columns 3 and 4 show the approximate specific gravity, per cubic foot, compared with the bulk per ton of each kind. These columns are offered as the only test by which the fitness of different railway gauges, or the proper distance between the rails of the wagon track for the conveyance of traffic, can possibly be established, in accordance with the relation existing between the bulk and weight of the prevalent classes of product to be conveyed. They show that the fitting gauge for the conveyance of light products must be wide, while that for conveying heavy minerals may be narrow, whilst the wide gauge suits both light and heavy goods or materials. They prove that the 5 ft. 6 in. gauge, established for India in 1851, was the most suitable that could have been selected; and that the 3 ft. 3 in. gauge, now sought to be established, would not merely introduce the inconvenience of a break of gauge, as in England, but, in addition, would inflict a serious wound on the commerce of India, by providing a wholly unsuitable means of transport for the products to be conveyed.

	Cubic feet.
The first seven kinds of products (1 to 7) comprise goods of the lightest specific gravities, ranging from 224 to 90 cubic ft. per ton, and make an aggregate of	8,232,802
The next fifteen kinds (8 to 22), ranging from 80 to 50 cubic ft. per ton, make an aggregate of	7,202,827
The next fourteen kinds (23 to 36), ranging from 45 to 25 cubic ft. per ton, make an aggregate of	1,994,291
The last seven kinds (37 to 43), ranging from 20 to 5 cubic ft. per ton, make an aggregate of	270,735
All the above forty-three kinds, composing the entire year's traffic, varying in their specific gravities from 10 lbs. to 443 lbs. per cubic foot of bulk, make a total of	17,700,655

The goods so classified are in every respect adapted for transport in the existing wagons of the 5 ft. 6 in. gauge, whilst only the last seven heavy kinds, 37 to 43, or less than one sixty-fifth part in bulk of the products, would be suitable for a 3 ft. 3 in. gauge.

The table also shows that nine-tenths of the ordinary traffic of populous districts consist of commodities applicable to the food and clothing, &c., of man, requiring bulky space in the vehicles of transport, and this applies equally to populous districts where minerals are produced. The minerals can be conveniently carried on a medium wide gauge. The bulky goods cannot be economically conveyed on a narrow gauge, which must necessarily in that case consist of double lines; nor can passengers, oxen, horses, infantry, cavalry, field artillery, or siege artillery. These must all be furnished with a wide through gauge line, whether short special branches of narrow gauge be used for minerals or not, as in Wales, in order to reach the nearest station on the general traffic line of the country. It is a most costly error to lay down a narrow-gauge line merely to initiate the improvement of a waste district. The right course in that case is to construct, when necessary, a good smooth carriage road from the most convenient station of the nearest railway, and laid out upon the best levels that the country will admit, to secure the power of ultimately laying down rails to the proper national gauge, but placing upon the road, in the interim, Thomson's traction engine and trucks without rails. Such a road, furnished with its train complete, need not cost more than £500 to £1,000 per mile, exclusive of large bridges; and when the district is developed up to the requirement of a regular railway, the rails can be laid down, and the road traction engine, with its train, can be moved forward to some other district requiring its temporary services without any loss or waste whatsoever. Twelve miles of improvable waste district can thus be put under a process of rapid improvement for what each single mile would cost upon the narrow gauge system.

The plea of economy urged by those who advocate the narrow-gauge lines for general traffic is a misleading delusion. Their complication where there is the amount of traffic requiring a railway would make them more costly, even as single lines, than those constructed on the proper gauge. The table refers to a line on the 5 ft. 6 in. gauge, 312 miles in length, with a ruling gradient of one in five hundred. The last extension of this line, 80 miles in length, has just been completed under the chief Resident Engineer, Mr. Francis Mathew, M. Inst. C.E., within an expenditure of £5,500 per mile. Had Mr. Mathew's rate of cost been the rule, instead of the exception, in constructing Indian railways, their profits from the commencement would—calculated at the existing rates of freights and fares—have reached from 8 per cent. to 10 per cent. on the outlay, and in that case nothing would have been heard of the absurd proposal of a reduction of gauge. Hence the remedy, now called for, is an extension of Mr. Mathew's principle of economically constructing railways upon the standard East Indian gauge of 5 ft. 6 in. A reduction of that gauge, as now proposed must be much more costly, and would be utterly incapable of providing for the requirements of traffic when it reaches the inevitable development due to a sufficiently extended railway intercourse. This future increase may be estimated at least as amounting to thirty-fold the present agricultural production, with a consequent proportional increase of railway traffic.

On this line we have not had occasion to run more than three through trains daily each way; when the traffic requires four through trains each way it will be time to lay a second track; four through trains daily each way would necessitate sixteen crossings between the up and down trains. But sixteen crossings on a narrow gauge of 3 ft. 3 in. could only get through one-fifth of our traffic. Hence, had we been condemned to the narrow gauge we must have laid down a double line before we ever opened for traffic. In fact, the great characteristic of single line working is, that the number of crossings between up and down trains increases as the square of the number of through trains daily each way : on, say a twelve-hours' journey, our present three trains would give nine such crossings—quite complication enough. Their equivalent on the narrow-gauge single line would require the square of fifteen, or 225 crossings in a day—an utter impossibility!

Every competent engineer who lays down a line of railway must feel responsible for securing that what he provides shall suffice, not for the mere wants of the present day, but for keeping pace with the largest development of traffic that shall ever take place, without undoing anything that has been done.

In this view the principal subjects for consideration in any estimate as to the future maximum amount of traffic for which he or his successors must provide transport, may be summarized as follows:—

First.—That only about one-fourth of the surface of India is yet cultivated, owing to the deficiency of roads for the conveyance of produce to market.

Second.—That ignorance of sound principles in agriculture now limits the acreable produce of the cultivated land to less than one-fourth of what it must hereafter be when the present wise intentions of Government regarding agricultural instruction shall have had time to operate.

Third.—That the intended increase of irrigation from reservoirs, dams, and canals, &c., must still further enormously increase the surplus agricultural produce, for which transport must be hereafter provided.

Fourth.—That mineral produce is likewise only awaiting something like human energy for its further development.

Fifth.—That the trunk lines of India are enormously in excess of length as compared with those of England; a fact which must proportionally increase the comparative goods-truck accommodation that will in future be required upon Indian trunk lines.

Sixth.—That the London and North Western Railway Company, on a much wider gauge than that here objected to, have already been obliged to *quadruple* their 4 ft. 8½ in. tracks over one-third of their main line between London and Lancashire.

These memoranda may be appropriately closed with the following extract from the Victorian Correspondent's letter, dated Melbourne, 14th August, which appeared in the 'Times' of Tuesday, October 1st, 1872:—"A remarkable change in the views of our Lower House has served to illustrate the use of the Upper, to which our self-styled Liberals object as a mischievous obstruction. In considering the extension of our railway system in November, 1871, the Assembly, yielding to a popular cry for cheap construction and to the recommendations of the press, determined, in opposition to the decidedly expressed opinion of Mr. Higinbotham, the engineer-in-chief, to make the new lines on a 3 ft. 6 in. gauge, instead of continuing the former of 5 ft. 3 in. The Council, after hearing the evidence of the engineer and others, refused to pass the Construction Bill without a clause requiring the assent of both Houses to any change from the old gauge. The Assembly disagreed with the amendment, and the matter remained in abeyance until this Session. In the interval, our Agent-General had collected the opinions of eminent engineers from different parts of the world, which supported Mr. Higinbotham's view. The matter has been again discussed, and the Assembly reversed its former judgment by a majority of 42 to 10 against the break of gauge. The new lines are now being constructed on the 5 ft. 3 in. gauge."

TABLE giving the CLASSIFICATION and SPECIFIC GRAVITY of GOODS conveyed over the BOMBAY, BARODA, and CENTRAL INDIA RAILWAY, in the Years 1871 and 1870.

No. of Kind.	Classification of Goods conveyed.	Specific Gravity of each kind of Goods.		Total Goods carried during Year 1871.		Specific Gravity of each class of Goods.		Total Goods carried during Year 1870.	
		Weight per cubic foot in lbs.	Cubic feet per ton in Bulk.	Tons.	Cubic Feet.	Weight per cubic foot in lbs.	Cubic feet per ton in Bulk.	Tons.	Cubic Feet.
1	Unpressed cotton	10	224	220	49,280			121	27,104
2	Furniture	11	200	2,185	437,000			1,924	384,800
3	Half-pressed cotton	12	186	31,009	5,767,674			30,526	5,677,278
4	Cotton seeds	12	186	3,932	731,352			7,155	1,330,830
5	Wool	16	140	984	137,760			786	110,040
6	Fruit and vegetables	22	100	5,526	552,600			6,876	687,900
7	Eggs	25	90	176	15,840			165	14,850
Class 1	Averages and totals	13	174	44,032	7,691,506	13	173	47,553	8,232,802
8	Grass	28	80	1,973	157,840			1,021	81,680
9	Sundries	28	80	5,496	439,680			6,027	482,160
10	Bagging	32	70	1,178	82,460			1,047	73,290
11	Commissariat stores	32	70	1,393	97,510			1,288	90,160
12	Full-pressed cotton	32	70	7,492	524,440			5,359	375,130
13	Flax and hemp	32	70	27	1,820			65	4,550
14	Groceries	37	60	3,167	190,020			2,541	152,460
15	Grains and seed	37	60	45,237	2,714,220			77,627	4,657,620
16	Twist	37	60	1,325	79,500			1,452	87,120
17	Sugar	40	56	9,510	532,560			8,687	486,472
18	Soap	40	56	520	29,120			629	25,160
19	Firewood	40	56	5,582	312,592			2,616	104,640
20	Salt	44	51	4,348	221,748			1,900	96,900
21	Lime	44	51	1,665	84,915			835	42,585
22	Dry fruits	45	50	7,664	383,200			8,858	442,900
Class 2	Averages and totals	37	60	96,577	5,851,625	37	60	119,952	7,202,827

23	Jagree (molasses)	50	45	17,286	777,870			12,865	578,925
24	Kupas (seed cotton)	50	45	205	9,225			1,404	63,180
25	Mowra (flowers which produce spirit)	50	45	11,925	516,625			11,402	513,090
26	Timber	50	45	6,122	275,490			6,425	289,125
27	Ghee (clarified butter) . . .	56	40	1,142	45,680			1,062	42,480
28	Oil	56	40	843	33,720			804	32,160
29	Piece goods	56	40	6,023	240,920			5,434	217,360
30	Rape	56	40	408	16,320			439	17,560
31	Beer and spirits.	62	36	1,045	37,620			526	18,936
32	Coal	80	28	1,146	32,088			1,734	48,552
33	Paper	80	28	504	14,112			550	15,400
34	Tobacco	80	28	4,724	132,272			4,601	128,828
35	Opium	86	26	631	16,406			520	13,520
36	Machinery	90	25	551	13,775			607	15,175
Class 3	Averages and totals	54	41	52,555	2,162,123	55	41	48,373	1,994,291
37	Cutlery	112	20	38	760			42	840
38	Potash	112	20	377	7,540			282	5,640
39	Sand	112	20	135	2,700			321	6,420
40	Colour	124	18	1,587	30,366			1,442	25,956
41	Bricks	132	17	676	11,492			2,257	38,369
42	Stone.	148	15	2,384	35,760			10,891	163,365
43	Metal	443	5	4,549	22,745			6,029	30,145
Class 4	Averages and totals	203	11	9,746	111,363	176	12	21,264	270,735
	Averages and totals	28	78	202,910	15,816,617	30	75	237,142	17,700,655

VI.—Report of Mr. J. E. Tanner, M. Inst. C.E., on a Light Railway to connect the larger towns of the Punjâb with Lahore.

My Dear Saunders, *December* 6, 1861.

I herewith send you the estimate you asked me to make out. I have made it out for 50 (fifty) miles, as the rolling stock, &c., will be about the same for every 50 miles.

The expense of the construction of the proposed railway is not much when we consider that money is about to be expended on the conservancy of the Indus and Jailaw, and that money spent on such conservancy will be an annual expense to the Government of the Punjâb, for do what one may to procure a good channel, fit for the present or any kind of steam-boat (compatible with really quick traffic), the unstable soil of the bank with such a stream renders the said channel liable to be shifted in the course of a single night. All money expended on conservancy may be styled a venture; while such is not the case with money expended in converting one-half of the present roads into a light railway suitable for low speeds.

The annual expenditure of keeping up the Dâk horses and carts, bullock trains, &c., and the large staff of servants necessary for the present Dâk, would go towards the construction of the proposed light railway. The use of one-half of the roads has often been agreed in favour for a railway; and with the proposed speed an objection can hardly be raised, as 12 miles an hour is about the rate that the Dâk cart itself travels.

Yours sincerely,

(Signed) John Edward Tanner.

R. Saunders, Esq., Postmaster-General, Punjâb.

India is only ready for railways in the neighbourhood of such cities as Calcutta, Madras, Bombay, Kurrachee, Lahore, Umritsir, and Mooltan, where undoubtedly they will soon repay the money expended on them, to connect Kotree with Mooltan, Lahore with Peshawur, Lahore with Ferozepoor, Rawul-Pindee with Murree, Umballah with Kalka, and Meerut with Delhi; between which towns the traffic is very great, but not sufficient to induce the Government to grant the 5 per cent. guarantee on the enormous outlay necessary for a railway, for it could not pay as a matter of speculation for years to come. It behoves us, therefore, to procure a means of carrying goods and passengers with a certainty and speed much greater than can be attained by horses and camels. Surely this could be performed by a light railway, and the traffic carried by light engines on the longer lines, and by horses on the shorter branches. Speed with the light engines not to exceed 8 miles for goods and 12 miles for passengers. In this way the traffic would increase in the same proportion as if a railway (proper) had been constructed.

When the traffic requires greater speed, then a railway can be constructed with a certainty of paying; and the light rails that had been used could then be laid down between other towns that would be ready for such a branch line.

Rails.—The rails I would propose would be of the weight of 28 lbs. a yard run, which would suit a traffic of 8 miles for goods and 12 miles for passengers. Between Kotree and Mooltan I would propose a rather heavier rail—32 lbs. a yard—for that is the only link wanting of W. P. Andrew, Esq.'s scheme, and must, as he always foretold, make Kurrachee the best port for all passengers from India to England, and will bring even Calcutta a week nearer to England.

Sleepers.—The difficulty in procuring wood for sleepers in the Punjâb makes it almost a necessity that Greave's cast-iron pots should be used. They are not difficult in packing while laying the line; and in moving the line at any time to another part of the country we should not be put to the expense of renewing worn-out sleepers, while the extra expense in the first instance is very slight.

Earthwork.—If one-half of the road is allowed to be used for the railway, the bridges and earthwork will be very slight.

Fencing.—Fencing to be made of balrol or other hard wood, except when water is easily procurable, and then a low mud wall.

Tank and Stations.—As there is a well close to the road at all the serrails, a small tank made of wood capable of containing water for 3 (three) engines, and a shed for receiving goods, is all that will be necessary; and the serrails and Dâk bungalows will answer amply for station accommodation for the present. When the traffic requires more, such a station as is suited to the requirements can easily be built.

Engines and Rolling Stock.—The engines would cost in England about £800 to £1,000. The trucks must differ according to the kinds of traffic expected.

Laying the Line.—The rails from their lightness will be easy to handle, which will overcome the great difficulty we have in India of laying heavy rails. The rails might be laid at the rate of six miles a month, with two English platelayers for superintending the gangs. As camels could carry the rails easily, there would be no great difficulty in getting the rails from the river bank, or carrying our own material.

Expense for the construction of 50 miles of proposed light railway	£100,000
Per mile (exclusive of rolling stock)	2,000

Crossing the Rivers.—The best way for crossing the rivers would be by a steam ferry. A pier would have to be run out on each side of the river; and as there will be no heavy superstructure, and the trains themselves will be light, they need not be expensive, but only sufficiently strong to prevent their being washed away by the floods.

(Signed) JOHN EDWARD TANNER, M. Inst. C.E.

February 11, 1873.

T. HAWKSLEY, President,

in the Chair,

At the commencement of the proceedings :—

Mr. HAWKSLEY, President, stated that the following communication had been received in acknowledgment of the vote of sympathy and condolence with the Empress Eugénie passed by the Institution on the occasion of her recent bereavement[1] :—

"Camden Place, Chislehurst,
le 10 février 1873.

"MONSIEUR LE PRÉSIDENT,

"Vous avez, au nom des Membres de l'Institut des Ingénieurs Civils de Londres, dont l'Empereur faisait partie comme Membre honoraire, fait parvenir à Sa Majesté l'Impératrice une adresse de sympathie et de condoléance.

"Sa Majesté en a été vivement touchée et m'a chargé de vous en exprimer ses remercîments en son nom, comme en celui de S.A.S. le Prince Impérial et de tous les autres membres de la famille Impériale.

"Veuillez agréer, Monsieur le Président,

"l'assurance de ma Considération très-distinguée,

(Signed) "DUC DE BASSANO.

"Monsieur le Président de l'Institut des Ingénieurs Civils, Londres."

The discussion upon the Paper, No. 1,365, "The Relative Advantages of the 5 Ft. 6 In. Gauge and of the Mètre Gauge for the State Railways of India, and particularly for those of the Punjâb," by Mr. W. T. Thornton, was resumed and continued throughout the evening.

February 18 and 25, 1873.

T. HAWKSLEY, President,

in the Chair.

The discussion upon the Paper, No. 1,365, "The Relative Advantages of the 5 Ft. 6 In. Gauge and of the Mètre Gauge for the State Railways of India, and particularly for those of the Punjâb," by Mr. W. T. Thornton, occupied both evenings to the exclusion of any other subject.

[1] *Vide* ante, p. 138.

March 4, 1873.

T. HAWKSLEY, President,
in the Chair.

The following Candidates were balloted for and duly elected :—JOHN BENNETT, GEORGE JAMES HERVEY GLINN, and ROBERT HARRIS, as Members; JOHN BARKER, THOMAS HOLMES BLAKESLEY, Stud. Inst. C.E., PHILIP CARPENTER, SAMUEL BROTHERS DARWIN, EDWARD GILES, Lieut. FREDERICK WILLIAM JOSEPH, B.S.C., WILLIAM HENRY KING, Stud. Inst. C.E., CHARLES EDWARD NICHOLAS, FRANCIS JAMES ODLING, Stud. Inst. C.E., ARTHUR RICKETTS, RICHARD EDWARD SPEAKMAN, THOMAS SULLOCK STOOKE, GEORGE THOMPSON, Lieut.-Col. JOHN SALUSBURY TREVOR, R.E., JOHN WHITTINGHAM, and GEORGE HENRY WOOD, as Associates.

It was announced that the Council, acting under the provisions of Sect. III., Cl. VII., of the Bye-Laws, had transferred WILLIAM FRANCIS from the class of Associate to that of Member.

Also, that the following Candidates, having been duly recommended, had been admitted by the Council, under the provisions of Sect. IV. of the Bye-Laws, as Students of the Institution :—THOMAS GEORGE BOND, FRANK FERGUSON BUCKHAM, AUGUSTUS MARIUS HEATON, MONTAGUE MARTINDALE, and EDWARD THOMPSON.

The discussion upon the Paper, No. 1,365, "The Relative Advantages of the 5 Ft. 6 In. Gauge and of the Mètre Gauge for the State Railways of India, and particularly for those of the Punjâb," by Mr. W. T. Thornton, was resumed and continued throughout the evening.

March 11 and 18, 1873.

T. HAWKSLEY, President,
in the Chair.

The discussion upon the Paper, No. 1,365, "The Relative Advantages of the 5 Ft. 6 In. Gauge and of the Mètre Gauge for the State Railways of India, and particularly for those of the Punjâb," by Mr. W. T. Thornton, occupied both evenings to the exclusion of any other subject.

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